GLASSHOUSE CROPS RESEARCH INSTITUTE

ANNUAL REPORT

1959

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THE GLASSHOUSE CROPS RESEARCH INSTITUTE

The Glasshouse Crops Research Institute was established on the 8th September, 1953, as a company limited by guarantee, but without share capital, under the Companies Act of 1948. Its registered office is at Littlehampton, Sussex, where the main research station is being developed. The Institute succeeded the Experimental and Research Station at Cheshunt, which was in existence from 1915 to 1954, and also took over the work of the Mushroom Research Station at Yaxley, which functioned from 1946 to 1954.

In the Memorandum of Association the principal object for which the Institute has been established is stated as follows:

> "To promote scientific research bearing on the cultivation of glasshouse crops and mushrooms, and of bulbs, flowers and shrubs grown in the open, and on matters ancillary thereto".

The Institute is administered by a Governing Body consisting, at present, of fourteen members including the Chairman, Mr. T. Ainslie Robertson. Six members are well-known commercial growers who represent the branch of horticultural industry served by the Institute, six are eminent scientists, and one is a Senior Education and Advisory Officer of the Ministry of Agriculture. The Governing Body is appointed by the Minister for Science and the Minister of Agriculture, Fisheries and Food.

The Institute is financed almost entirely by grants from the United Kingdom Treasury. Since 1st April, 1956, these have been administered by the Agricultural Research Council, which exercises general supervision over the Institute's staffing and research programme.

The Institute has a Subscription Scheme whereby growers and others may associate themselves with its work. For a modest annual payment they may obtain certain privileges which enable them to take a closer and more personal interest in the research that is being carried out at the Institute. The principal minimum subscription rates are five guineas per annum for firms or companies, and two guineas per annum for growers working on their own account or for other individuals interested. A special reduced rate applies to those overseas. Those subscribing receive as their main privileges a copy of the Annual Report and an invitation to attend the annual Open Day. Further particulars of the Scheme may be obtained from the Secretary of the Institute.

The Institute's research station at Littlehampton is situated in the heart of the important West Sussex glasshouse area. This is also an important area for mushroom production. The station is thus well placed for its work and for maintaining contact with important sections of that branch of horticultural industry which the Institute has been set up to serve. The research station covers 98 acres, and includes 41 acres arable and about $18\frac{1}{4}$ acres of rough grazing, the remaining area being kept as amenity grassland. The greater part of this land is required as a reserve for future work with outdoor crops, for the supply of loam, and for resoiling the glasshouses when experimental work requires it.

The Institute's physical development has reached an intermediate stage. In addition to an administration building which has just been completed there is a well-equipped block of laboratories with an annexe for special services. There are also 1.55 acres of permanent glass for large scale experiments and trials, as well as research glasshouses for work in the fields of plant physiology, plant pathology, chemistry and crop protection. A special unit, including three growing houses, for work on mushrooms completes the research facilities, which are supported by a wide range of ancillary buildings, such as boiler houses, potting sheds, stores, etc. Other research facilities are being planned.

The scientific and experimental staff of the Institute at present number 31, most of whom are honours graduates.

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GLASSHOUSE CROPS RESEARCH INSTITUTE

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Professor F. G. GREGORY, D.SC., F.R.S.
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SCIENTIFIC STAFF

Plant Breeding

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J. W. M. SMITH

Assistant (*Scientific*)
Miss P. R. AINSLEY (*from 29.12.59*)

Plant Physiology

E. R. LEONARD, D.SC. (Lond.), A.R.C.S., M.I.BIOL.
H. R. B. HACK, B.A. (Cantab.)
A. J. COOPER, B.SC. (Lond.), PH.D. (Reading)

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Chemistry

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J. H. L. MESSING, B.SC. (Wales) (*seconded to British Guiana*)
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Miss E. J. WINGATE

Plant Pathology Division

L. Broadbent, D.Sc. (Lond.), Ph.D., M.I.Biol.

Entomology

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Miss B. Gurney

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Miss D. G. Gandy, M.Sc. (Lond.)
Miss O. M. Stone, M.A., Ph.D. (Cantab.)

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Virology

M. Hollings, B.Sc., M.I.Biol. (*from 1.5.59*)
R. Howles, B.A., Ph.D. (Cantab.)

Assistants (*Scientific*)
R. Pawley, P. Weatherdon (*from 4.5.59*)

Crop Protection

W. H. Read, M.Sc. (Birmingham), F.R.I.C.
R. J. Smith, B.Sc., Ph.D. (Lond.)
J. T. Hughes, B.Sc. (Lond.), A.R.I.C.
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Miss P. M. Smith, B.Sc. (Lond.) (*from 4.8.59*)

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Miss J. Martin, Miss B. Hotston, Miss B. Finch

Horticulture

G. F. Sheard, M.Sc. (Leeds) (*from 1.5.59*)
A. C. Bunt, N.D.H. (*from 1.10.59*)

Technical Services Unit

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Assistant (Scientific)

Miss G. MARSH

Maintenance Staff

R. MINGAY, B. ROCKALL

Scientific Liaison Officer

G. F. SHEARD, M.SC.

(*also Head of the Horticultural Department*)

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Accounts Officer

D. M. HART, A.C.I.S. (*from 1.12.59*)

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NURSERY STAFF

Nursery Manager and Demonstrator

J. M. EVANS, N.D.H.

Foreman

T. W. SYER (*until 28.11.59*)

Boiler Attendant and Fitter

R. FROST

Assistants (*with more than four years' service at 31.12.59*)

F. BLAKE (*31 years*), L. TOMS, P. DAWES, W. HOTSTON, Miss R. MILLS, Mrs. J. HOTHER, S. BARNETT, Miss A. RICH

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I. INTRODUCTION

The year under review was one of considerable activity. There was a further building up of staff, with two important posts filled, and a resumption of the physical development of the Institute. A notable feature of the year was the extraordinary number of visitors, including many large parties, which gave us the satisfaction of knowing that the Institute is now well and truly on the map and its work is proving of interest to a very wide circle of people.

The highlight of the year, however, was the visit of an A.R.C. Visiting Group in October. The Group's function was to review the Institute's research programme, advising where any changes might appear to be necessary, and to discuss and agree with the Director the organisation, staff and facilities required for implementing it. The preparation of a draft programme for the Group's consideration involved the staff in a great deal of work, but the critical examination of research projects which this entailed and the subsequent helpful discussions with members of the Group was an exercise of the greatest value. The Visiting Group's report was not received until after the period covered by this Report, and its recommendations will therefore not be reflected until next year, but it is possible to say that it outlines a very sound basis for the Institute's work over the next few years and gives promise that the necessary facilities will be made available. We are indeed most grateful to the Group for the very careful consideration they gave to the Institute's affairs and for their most helpful advice and support. The industry may be assured that as a result of the Group's deliberations the Institute's research organisation has been considerably strengthened to meet the grower's needs.

Governing Body

It is with the greatest regret that we have had to take leave of Professor W. Brown as a member of the Governing Body. He served on it from the Institute's inception in 1953 until the rules relating to age compelled his retirement on 25th October, 1959. No one could have taken a greater interest in the Institute than Professor Brown, and his advice and help, always given in the kindest manner, were invaluable. As Chairman of the Staff and Research Committee the calls on his time were many, but his services were always freely given.

Professor McGregor Skene also retired from the Governing Body on 25th October, 1959, for a similar reason, having served since October 1955. Professor Skene was another staunch supporter of the Institute, and although his other engagements prevented us from seeing as much of him as we should have liked, his contributions at Governing Body meetings were always very sound and much appreciated.

We offer our very best wishes for the future to Professors Brown and Skene, and hope we shall continue to see them from time to time. Their successors had not been appointed by the end of the year.

The Fifth Annual General Meeting was held on 28th January, 1959, when the Chairman's Report and the Accounts and Balance Sheet for the year ended 30th September, 1958, were approved and adopted. Two ordinary meetings of the Governing Body, the Thirteenth and Fourteenth, were also held during the year for general business.

The General Purposes Committee met at the Institute on 26th February and dealt with certain other business by correspondence. The Staff and Research Committee met in London on 27th February and 1st June, primarily to interview candidates for vacancies, although at the earlier meeting matters connected with the research programme were also considered. This Committee

held a further meeting at the Institute from 28th to 30th September and gave very detailed attention to the final drafting of the research programme drawn up for the Visiting Group.

The special Heating Sub-Committee held a short meeting at the Institute on 10th June.

Staff

Mr. G. F. Sheard, M.Sc., who was formerly Director of the Fairfield Experimental Horticulture Station in Lancashire, took up his duties as Head of the new Horticultural Department on 1st May. Mr. Sheard also functions as the Institute's Scientific Liaison Officer, with the responsibility for making the Institute's work known not only to visiting growers and scientists, but also outside the Institute by means of talks, lectures, etc., and by contacts with the Advisory Service.

Another Head of Department was also appointed on 1st May, Mr. M. Hollings, B.Sc., taking over responsibility for a new Virology Department set up within the Plant Pathology Division under Dr. Broadbent. Mr. Hollings worked at the Ministry of Agriculture's Plant Pathology Laboratory at Harpenden for nine years, and made a reputation for himself in the field of virus diseases, particularly those affecting ornamentals.

Mr. A. C. Bunt, N.D.H.(Hons.), formerly in Mr. Lawrence's Department at the John Innes Horticultural Institution, joined the Institute on 1st October to work under Mr. Sheard as an Experimental Officer. Miss P. M. Smith, B.Sc.(Hort.), was appointed as an Assistant Experimental Officer on 1st August for mycological work in the Crop Protection Department.

To provide additional assistance in the Secretary's office, needed as a result of the increasing administrative work arising from the Institute's development, Mr. D. M. Hart was appointed as an Executive Officer on 1st December. A Typist/Telephonist was also added to the office staff.

There was one replacement among the staff of Assistants (Scientific), to fill a vacancy arising through marriage, and three new appointments. These changes are shown in the staff list published at the beginning of this report.

Five students were employed for varying periods during the summer to assist with the recording of the glasshouse experiments and for other duties.

The Nursery Foreman, Tom Syer, resigned to take another post at the end of November, after combined service to the Institute and its forerunner, the Experimental and Research Station at Cheshunt, totalling 33 years. He moved down from Cheshunt in the early days of the Institute and did valuable work in getting the nursery going.

We are pleased to record the award of a Ph.D. to Mr. R. J. Smith, of the Crop Protection Department, for a Thesis entitled "Some observations upon the fungitoxic and phytotoxic properties of certain quinones and related compounds".

Our congratulations also go to Miss V. A. Gentle, of the Crop Protection Department, and Mr. D. Cooke, Statistician, who were married on 3rd October.

Internal organisation

As will be evident from the staff appointments reported above two new research departments were set up, for Horticulture and Virology. The Virology Department is one of a trio of departments comprising the Pathology Division, which will eventually be completed by the addition of a section for Nematology.

Capital developments

The development of the Institute was carried a stage further during the year, and much time was also spent planning facilities still required. The major project undertaken was the administration building which, as mentioned last year, had had to be postponed because of Government restrictions on capital expenditure. When approval to start building was eventually given, the work proceeded smoothly, keeping closely to the timetable, and was almost finished by the end of the year. The new building, which is on two floors, provides accommodation for the Director, the Secretary and the administrative staff, as well as for Mr. Sheard in his dual capacity as Head of the Horticultural Department and Scientific Liaison Officer; it also houses the library, which will now have ample room for expansion for some time ahead, and a meeting room. It makes a very welcome addition to the Institute's facilities. An additional grant was received to furnish the building on a reasonable scale.

The new building will release much-needed accommodation in the laboratory block, but when considering the staff expansion envisaged over the next few years it was evident that it would be insufficient unless activities not requiring full laboratory services could be accommodated elsewhere. The Architects therefore prepared a plan for extending the laboratory annexe, or preparation block as it is called, and although the proposal had not figured in the Institute's advance planning the A.R.C. received it with sympathy and made a further capital grant available for the purpose. The new extension will house the Technical Services Unit and provide office accommodation for the Statistician and his assistants, as well as computing rooms for the general use of the scientific staff. The new administration building and extension to the laboratory annexe have been skilfully planned by the Architects so that they harmonize well with the main laboratory block, to which they are connected by a covered way.

Against the time when the administrative staff and the library could be moved to the new administration building, plans and specifications were drawn up for the necessary alterations to the laboratory block so that vacated rooms could be brought into use as laboratories.

A number of minor capital works were undertaken during the year. A field laboratory for use in entomological and nematological work was built at the north end of the mushroom composting shed. A small timber-framed glasshouse, to be used principally for raising test plants for virus work but also as a general propagating house to meet the needs of the research departments, was erected to the south of the potting shed; this will considerably relieve the pressure for space in the research glasshouses. The alarm system was extended to the mushroom houses so as to give warning in the event of the steam humidification system failing to shut off. Finally, a small store for bonded alcohol and dangerous chemicals was built as an extension to the east of the laboratory preparation block.

Much time was spent on the planning of a special research glasshouse, with ancillary facilities, for virus and entomological work, and outline proposals were in fact submitted to the A.R.C. in April. Because of the cost and complexity of the project, however, approval in principle could not immediately be given, and at the end of the year further consultations were in progress with the A.R.C. and outside experts on some aspects of the design and on the engineering problems involved.

The proposals for modifying the heating system in the trial glasshouses received Treasury approval in principle and were given further consideration by the Governing Body's Heating Sub-Committee, which met on 10th June to discuss with the Architects the arrangements to be made for installing the new system. It was left to Mr. Sheard to draw up the final outline of the specifications for the scheme, and he was busy on this at the end of the year.

Reserve land

The work carried out on the reserve land is dealt with in the Nursery Manager's report (page 22), and will continue to figure in his report in future.

Subscription Scheme

Support for the Subscription Scheme continues to grow, and by the end of the year the numbers participating in the scheme were as follows:—

Companies or firms	76
Individuals	102
Overseas subscribers	13
	191

A.R.C. Visiting Group

Reference was made in an earlier part of this report to the A.R.C. Visiting Group which was received during the course of the year. For the record the members of the Group were as follows:

Chairman: Professor E. G. Cox	Professor of Inorganic and Structural Chemistry, University of Leeds
Professor O. V. S. Heath	Professor of Horticulture, University of Reading
Professor O. W. Richards	Professor of Zoology and Applied Entomology, Imperial College, London
Professor C. W. Wardlaw	Professor of Cryptogamic Botany, University of Manchester.
Mr. Donald Frampton	Until recently Chairman of Worthing and West Sussex Growers (N.F.U. Specialist Branch)
Mr. W. G. Alexander	Deputy Secretary, Agricultural Research Council
Mr. P. A. C. Thorne	Head of Plant and Soils Disivion, Agricultural Research Council
Dr. E. E. Cheeseman and Mr. G. G. Samuel	Scientific Assistants to the Secretary, Agricultural Research Council

Members of the Group made preliminary visits to the Institute during the summer, principally to see the experiments in progress in the glasshouses. The Group held its main meetings at the Institute from 28th October to 30th October, when the proposed research programme for the six-year period 1960/65, and the staff and facilities required for implementing it, were considered. Sir William Slater, Secretary of the Agricultural Research Council, attended the final meeting of the Group.

Miscellaneous

Staff social activities

The Staff Association held its usual Christmas party, which was again a great success. A fireworks display for the children was held at the traditional time in November. The activities of the Horticultural Society were hampered by the very dry summer, and it was not possible to hold the usual show.

Students

Mr. P. J. Sutton, the Ministry of Agriculture scholar, left us in September after completing the term of his post-graduate award. During the time he was at the Institute he was able to do a very useful piece of work on a subject of topical interest — the use of loamless composts — and a report on his experiments is published as a separate article (page 89).

Another student, N. Scopes, also completed his period of training at the Institute in September before proceeding to Wye College. During the latter part of his time he was attached to the Entomology Department and became concerned with improvements in the techniques for extracting larvae from mushroom compost.

At the request of the Commissioner for Eastern Nigeria we were pleased to accommodate a Nigerian, Mr. J. Uzo, to give him the opportunity of gaining first hand knowledge of tomato cultivation, and, particularly, of tomato breeding. Mr. Uzo spent six months in the Plant Breeding Section under Mr. Darby, and it is hoped that the experience he gained will be of value to him in his post as Agricultural Supervisor at the Agricultural Department's Regional Market Garden at Enugu, Eastern Nigeria.

Liaison

Liaison was maintained with other experiment stations and with many official bodies through representation on various committees, as listed in previous reports. In this way the Institute is kept in close touch with activity in the section of horticulture covered by its terms of reference. It is also a pleasure to record the continuance of very friendly relations with the National Agricultural Advisory Service, a form of liaison which is invaluable in ensuring that the Institute is kept abreast of the industry's problems and in making the Institute's work known to growers.

Open Day

The third annual Open Day was held on 10th June, and the occasion was again blessed with excellent weather. About 167 visitors attended, a small increase over the previous year. A special preview was held for the benefit of the press on 29th May; this innovation seems to have been welcome, eleven journals and papers being represented.

Exhibitions and Shows

All Departments engaged in mushroom research combined to stage an exhibit at the Mushroom Industry Exhibition and Conference at Folkestone on October 6th—7th. Two members of the staff, Dr. Hussey and Mr. Flegg, took part in a "Brains Trust" during the course of the Conference.

Mushroom research

The Mushroom Growers' Association's Research Sub-Committee met at the Institute on 2nd March, 13th July and 20th October, these occasions again providing valuable opportunities for reviewing the progress of mushroom research with members of the staff concerned. At the July meeting it was an especial pleasure to have present Dr. E. B. Lambert, who is so well known for his researches on the cultivated mushroom at the U.S.D.A., Beltsville, U.S.A.

Conferences

The Institute was represented at the 4th International Mushroom Congress in Copenhagen from 18th to 26th July by the Director, Miss Gandy and Mr. Wyatt. Between them they presented six papers on behalf of themselves and their colleagues.

Other conferences attended by members of the staff were as follows:

Date	*Place*	*Subject or Title of Conference*	*Staff attending*
Jan. 8th	Starcross	N.A.A.S. Conference on potting loams.	Director P. J. Sutton
March 5th	London	N.A.A.S. Plant Pathologists' Conference on virus testing.	Dr. L. Broadbent
March 24/26th	Oxford	A.R.C. Conference of Research Workers on Insecticides, Fungicides and Herbicides.	W. H. Read J. T. Hughes
April 8th	Brighton	Horticultural Education Association Spring Conference.	Dr. L. Broadbent
April 28/29th	East Malling	Symposium of European Acarologists.	Dr. N. W. Hussey Miss V. A. Gentle (now Mrs. Cooke)
April 29/30th	Spalding	N.A.A.S. 2nd Bulbs Conference.	Dr. L. Broadbent D. Cooke
May 5th	Birmingham	Electronic digital computers.	D. Cooke
June 11th	Farnham	Provenance of forest tree seed.	Dr. N. W. Hussey
July 4/6th	Oxford	Conference of British Entomologists.	Dr. N. W. Hussey
Oct. 1/2nd	London	Institute of Biology Symposium on biological problems arising from the control of pests and diseases.	Dr. L. Broadbent Miss M. Ebben
,, ,,	,,	Symposium on Enzymes (Society of Chemical Industry—Food Group).	G. E. Hobson
Oct. 6/7th	Folkestone	Mushroom Industry Exhibition and Conference.	Dr. N. W. Hussey P. B. Flegg I. J. Wyatt G. F. Sheard
Oct. 22nd	Exeter	N.A.A.S. Horticultural Conference.	G. F. Sheard
Nov. 16/18th	Sunningdale	N.A.A.S. Horticultural Advisory Officers Refresher Course.	Dr. L. Broadbent G. F. Sheard Dr. G. W. Winsor Dr. A. J. Cooper L. A. Darby

Talks, lectures, papers by staff

The increasing tempo of the Institute's work is well reflected in the large number of talks and lectures given by members of the staff, and by the papers they delivered at various conferences, some of which have been listed above.

The papers given at the 4th International Mushroom Congress in Copenhagen were as follows:

"Mushroom research in the United Kingdom"	Director
"Biology of mushroom Phorids"	Dr. N. W. Hussey
"Some aspects of Cecid biology of importance in mushroom culture"	I. J. Wyatt
"Cecid control by incorporation of insecticides in composts"	Dr. N. W. Hussey and I. J. Wyatt
"The functions of the compost and the casing layer in relation to fruiting and growth of the cultivated mushroom"	P. B. Flegg
"Watery Stipe—a preliminary investigation"	Miss D. G. Gandy

The Director gave a talk on the Institute's tomato research at the N.A.A.S. Horticultural Conference held for the benefit of growers at Beverley, Yorkshire, on 22nd January. He was also interviewed by Franklin Engelmann for the B.B.C's "Down your way" programme, which was broadcast on 12th July, and gave an account of the work of the Institute. He gave further talks on the Institute's work at a growers' conference held by the West of Scotland Agricultural College at Ayr on 20th November.

Other talks, lectures, and papers given by members of the staff were as follows:

January 8th	P. J. Sutton	"The literature on standard seed and potting composts" (at the conference on potting loams at Starcross)
January 15th	W. H. Read	"Chemical soil sterilisation" (at a growers' conference at Swanley)
January 29th	W. H. Read	"Materials and their formulations available for use as insecticides and fungicides in glasshouses" (at a N.A.A.S. Horticultural Advisory Conference in Torquay)
February 23rd	Dr. L. Broadbent	"The local production of healthy seed potatoes" (at a N.A.A.S. and potato growers' meeting at Chatteris)
March 12th	L. A. Darby	"Plant breeding" (at a meeting in Guernsey arranged by the Guernsey Growers' Association)
May 6th	Dr. L. Broadbent	"Virus diseases" (at the Institute of Park Administration at Ramsgate)
June 11th	Dr. N. W. Hussey	"Biology of *Megastigmus*" (at the conference at the Forestry Commission Research Station at Farnham)

June 12th	Dr. L. Broadbent	"Spread and control of plant viruses" (to Colombo Plan Students at Chesterford Park, Cambs.)
September 29th	G. F. Sheard	"A review of tomato growing research in the U.K.)" (at the W. Scotland Agricultural College, Tomato Growers Residential Conference, Glasgow)
October 7th	G. F. Sheard	"Irrigation and water requirement of glasshouse crops" (to West Sussex growers in Worthing)
October 22nd	G. F. Sheard	"Research into factors affecting tomato quality" (at the N.A.A.S. Horticultural Conference, Exeter)
November 4th	Dr. L. Broadbent	"Locally produced seed" (to a N.A.A.S. potato conference at Cambridge)
November 9th	G. F. Sheard	"Tomato quality" (to the Nazeing and District Growers Discussion Group)
November 12th	G. F. Sheard	"Tomatoes" (to the N.W. Sussex Growers Mutual Aid Group)
November 17th	G. F. Sheard	"The work of G.C.R.I." (to the Scottish Growers Federation, Glasgow)
November 16/18th	Dr. L. Broadbent	"The effect of virus on tomato quality"
	Dr. G. W. Winsor	"Nutrition and composition of tomatoes in relation to fruit quality"
	Dr. A. J. Cooper	"An interim report on progress in the blotchy ripening project"
	L. A. Darby	"Fruit quality in the tomato" (at the N.A.A.S. Horticultural Advisory Officers Refresher Course at Sunningdale)
November 20th	G. F. Sheard	"Tomato experiments at Rustington and Fairfield" and "Chrysanthemum experiments at Rustington and Fairfield" (at the West of Scotland Agricultural College Horticultural Conference at Ayr)
November 26th	Dr. L. Broadbent	"Potato virus diseases and their control" (Baywood Chemicals Ltd., staff training course at Rowhill, Kent)

December 3rd	G. F. Sheard	"The design, construction and heating of small glasshouses" (to the West Sussex Horticultural Club)
December 4th	I. J. Wyatt	"Cecidomyiidae as pests of cultivated mushrooms"
	Miss D. Gandy	"A transmissible disease of cultivated mushrooms ('Watery Stipe')" (to the Association of Applied Biologists)
December 7/14th	G. F. Sheard	"The glasshouse industry and the work of G.C.R.I. in relation to West Sussex" (at a W. Sussex Constabulary Training Course for Sergeants)
December 8th	Dr. Broadbent	"Spread and control of plant viruses" (to the Birmingham University Biological Society)
December 10th	Dr. L. Broadbent	"Plant pathology at the G.C.R.I." (to the N.W. Sussex Growers' Mutual Aid Group)

Visits

While in Copenhagen in July for the Mushroom Congress the Director visited a number of commercial nurseries in Denmark and Sweden to gain a picture of the glasshouse industry in those countries. In November the Director spent a week in Scotland visiting the Scottish Horticultural Research Institute at Mylnefield and then, with Mr. Sheard, nurseries in Lanarkshire and Ayrshire to see a cross section of the glasshouse industry in the Clyde Valley.

Dr. Broadbent visited the Netherlands in May to study the work being done at a number of research institutes and experiment stations. Mr. Darby went to Guernsey in March, primarily to give a talk to growers on the principles of plant breeding with particular reference to the tomato, and again visited nurseries in the island in June.

Numerous visits to research centres and growers' holdings in England were undertaken by the Director and staff in furtherance of the Institute's work. The increasing numbers of these contacts are another indication of the rapid way in which the Institute's work is developing.

Visitors

The wide interest taken in the Institute's work, not only in this country but also throughout the world, was shown by the very considerable number of visitors received during the year, including several large parties and many individuals from overseas.

We were particularly honoured to receive the Horticultural Education Association during the course of their spring conference at Brighton in April. This party numbered 150, the largest ever to visit the Institute, and involved a special effort on the part of the staff to ensure that the arrangements worked smoothly. All went well, and we like to think the members of the Association enjoyed their visit and profited by it.

In May two large parties of N.A.A.S. officers were received, 75 Horticultural Advisory Officers on the 13th and 52 Advisory Entomologists on the 14th. The Institute is now included in the list of research establishments regularly visited by N.A.A.S. Horticultural Advisory Officers to enable them to keep up to date with research in progress, so a visit from a similar party will become an annual event.

A visit which gave us great pleasure was that of the Director of the East Malling Research Station with 68 members of his staff in July. We were proud to have the opportunity of showing our paces to such a distinguished sister research institute.

The full list of visiting parties, with the approximate numbers in the party where known, was as follows:

April 9th	Horticultural Education Association (150)
April 27th	Students and Lecturer from Worthing College
May 7th	Surrey N.F.U. growers
May 13th	N.A.A.S. Horticultural Advisory Officers (75)
May 14th	N.A.A.S. Entomologists (52)
May 19th	Somerset Glasshouse Growers Club (35)
May 26th	Wiltshire Farmers (25)
June 11th	West Sussex Flowers Working Party
July 2nd	Dr. Tubbs and 68 members of East Malling Research Station
July 14th	Henfield Village Produce Association
July 28th	Nazeing and District Growers' Discussion Group
August 27th	Party of 30 Scottish growers
August 27th	West Sussex Tomato Working Party
October 23rd	Mr. Ockenden (science lecturer) and students, Bognor Training College
December 21st	West Sussex Tomato Working Party

Among overseas visitors were Dr. Walsh and a party from the Dublin Agricultural Institute, Eire, in June, a party of about 30 glasshouse growers from Holland who came on 23rd July, a small group of Italian growers who came earlier that month, and a party of Belgian horticulturists who came at the end of August. Other overseas visitors were as follows:

Australia:	B. A. B. Edwards, Senior Entomologist at Merrindale Research Station, nr. Melbourne. Dr. Kerr, Waite Institute.
Belgium:	R. De Jeyzer, Horticultural Adviser and Director of the Bedrijfsvoorlichtingsdienst for East Flanders. Fr. Vital, Director of Horticultural School, Wetteren. F. Geysen, Adviser for Engineering, East Flanders.
Brazil:	J. A. Deslandes, Seed Potato Certification.
British West Indies:	Dr. G. A. C. Herklots, Principal, I.C.T.A., Trinidad.
Canada:	Edward Sparkes, Leamington, Ontario. Dr. Spencer, Alberta University.
Denmark:	V. A. Hallig and Mr. Jensen, Horticultural Advisers to Danish Growers' Association. Dr. Ernst Hellmers, Royal Veterinary and Agricultural College, Copenhagen. Dr. C. Riber Rasmussen, Royal Veterinary and Agricultural College, Copenhagen. I. T. Hansen.
Germany:	N. Weiller. Prof. E. L. Nuernbergk, Botanic Laboratory, Hamburg.
Holland:	Dr. Bierhuizen. Prof. Thung, Wageningen.

Israel:	Mrs. Rivka Grunker, Nahalal. B. Eylan, Israeli Farmers' Association.
Italy:	Dr. G. Fois, Italian Institute for Foreign Trade, with Dr. L. Savi and other Italian colleagues. Prof. Antonio Ciccarone, University of Bari.
Kenya:	A. G. Whitehead.
Kuweit:	Khalil Salem, Agricultural Superintendent, Department of Education.
Madeira:	M. de Camara.
Malaya:	Prof. T. F. Dickson, Professor of Biochemistry, Medical School.
Malta:	J. Debrincat, Senior Agricultural Officer, Department of Agriculture.
Nigeria:	C. K. H. Martini, W.A.C.R.I., Ibadan. J. M. Thresh, W.A.C.R.I., Ibadan. T. M. Greensill, Superintendent of Department of Agriculture's Market Garden at Enugu.
Norway:	G. Rømcke Moe, Director of League of Gardeners. A. Hjeltnes, Director of Experimental Station of League of Gardeners.
Poland:	M. J. Skierowski, Senior Assistant, Department of Vegetable Crops, Institute of Soil Science and Cultivation of Plants.
South Africa:	E. McC. Callan, Rhodes University, Grahamstown. D. Wolfswinkel, Department of Agriculture.
Southern Rhodesia:	R. A. C. Doulton, Tobacco Research Board, Salisbury.
Sweden:	Hans Christensson, Vallingby. Beingt Wihart.
Uganda:	D. C. Thomas, Senior Botanist, Department of Agriculture.
U.S.A.:	Dr. A. M. Kofranek, Department of Floriculture, University of California. Dr. Sam Emsweller, U.S.D.A., Beltsville. Dr. E. B. Lambert, U.S.D.A., Beltsville. Prof. J. R. Culvert, Associate Professor of Floriculture, University of Illinois. Fred Buscher, Ohio Agricultural Extension Service, Ohio State University.
Yugoslavia:	Mr. Popov and Mr. Roncevic.

The number of United Kingdom visitors were too many to list in full, but it was a particular pleasure to receive Sir William Slater, Secretary of the Agricultural Research Council, on 19th June.

Acknowledgments

The Director again warmly acknowledges the support of the Governing Body and the help received from the Agricultural Research Council in numerous ways. He also records with pleasure his gratitude to the Institute's staff, of all grades, for their loyalty and hard work which contributed so much to the further progress of the Institute during the year.

THE NURSERY AND EXPERIMENT STATION

by

J. M. EVANS

The field trial glasshouses

Further consideration was given to the new propagating house, and a well-known firm was commissioned to design a metal-framed one which would meet the stated requirements as closely as possible. The areas occupied by the main crops (*viz.*, tomatoes, cucumbers, carnations and winter lettuce) were approximately the same as in 1958.

All tomato and cucumber houses were steamed except G1 and G2. Considerable improvement has been made in the physical condition of the glasshouse border soil by heavy dressings of bulky organic matter over the past five years. It is clear, however, that this practice will have to be continued at a high rate for some years to come if the panning of the surface layer, when hose watering, is to be reduced and the fertility and aeration of the soil improved. It is planned to extend the use of automatic watering equipment as an additional aid in reducing surface panning.

Heating system

The alterations made to improve the 4in. hot water system were successful. The replacement of the butterfly-type valves by plunger-type valves completely stopped circulation in periods of no demand. The fitting of orifice plates and the working of the two circulating pumps together in parallel gave a more even distribution of water, resulting in improvements in temperature control and in the uniformity of temperature distribution in the houses.

Constructional work

Concrete beds were laid in the southern half of carnation house E1 for work on carnation wilt diseases, the beds being designed so that drainage can be collected from each of the 48 plots.

A concrete apron was laid down to the north of the new mushroom houses to facilitate the delivery of manure to the composting shed.

General cropping

Tomatoes

Yields increased following the winter steaming programme, some tomato blocks being steamed for the first time. The earliest crop was grown in the two vineries F1 and F2, allocated to the Plant Breeder, which were planted on 18th February. Picking began on 8th April, and the crop was cleared on 20th July, by which time an average of 10 lb. per plant had been picked. The last planting, in Block B, was made on 14th March. This was earlier than in the previous year as the aeroplane houses C1 and C2 were used to ease the heavy demand for propagating space.

With the excellent summer weather the incidence of *Cladosporium* and *Botrytis* was low, but magnesium deficiency appeared early and was widespread. Routine spraying with a $1\frac{1}{2}\%$ solution of magnesium sulphate plus spreader kept the latter in check. Tobacco Mosaic Virus infection occurred early, and was widespread through the nursery. Foliar spraying with 2% urea had a marked ameliorating effect. Neither Red Spider Mite nor White-fly gave cause for frequent control measures.

Cucumbers

Two crops were again grown, the borders being steamed before each crop. Market returns from the 700 plants of hybrids with their parent varieties were good. A quantity of seed was also taken by the Plant Breeder.

Mildew occurred early in the season again, and was only partially controlled by routine spraying with "Karathane".

Carnations

The plantings in this block (E) grew away well in the summer of 1958, and cutting began in November, 1958. During twelve months' cutting average production exceeded 20 blooms per plant. Growth was particularly good in January and in the early spring months. The quality of bloom throughout was most satisfactory.

In the nutritional experiment in E2 the beds receiving low concentrations of liquid feed dried out more rapidly than those having higher concentrations. This made water application difficult since the experiment required uniformity of treatment.

Lettuce

Winter lettuce, selected for seed production from the previous crop, were flowered in the spring with reasonable success, the potted plants being grown in the corridor to the propagating unit.

Two vineries were planted in October, and cropping was completed by Christmas. About 340 lettuce were selected near maturity and potted to 9 in. clay pots for seeding, these were also housed in the propagating corridor.

Chrysanthemums (in pots)

The following varieties were added to the collection:

'Peace'	'Golden Fred Shoesmith'	'Improved Mayford Supreme'
'Pink Cloud'	'Madonna'	'Arundel'
'Avril Doig'	'Parade'	'Stylish'
'Maxine'	'Ardsheal Glory'	'Christmas Flame'
		'Sussex Bronze'

Roguing by visual means was carried out, and the varieties 'Pink Favourite' and 'Autocrat' were discarded because of infection with aspermy virus.

Ornamental plants

The usual bedding plants for decoration outside the glasshouses were raised, and an attempt was made to keep some indoor plants. It is hoped to increase facilities for glasshouse ornamentals in due course.

Research glasshouses

In order to release space in the pathology research glasshouse a prefabricated Dutch light glasshouse, 30 ft. x 20 ft., was erected by direct labour at the south end of the special purpose potting shed. Its main purpose is for the raising of test plants and for maintaining tested chrysanthemum stocks.

The mushroom research unit

The three houses have been fully cropped during the year. Some trouble has been experienced with the ventilating and humidifying systems in one house. The unit has been equipped with a straw chopper, and it is now possible to compost the stiffer straws being produced from present-day wheat varieties.

Warning system

The warning system to indicate failure of the heating system has been extended to the mushroom unit. The decision to install such a system at strategic points has been fully justified.

Reserve land

About 40 acres were put down to spring wheat and undersown with a long ley grass mixture. The wheat yielded 30 cwt/acre in spite of a light seeding to give the ley a better chance. Owing to the abnormally dry summer, however, the seeds mixture failed and had to be ploughed in. Preparations were made to directly re-seed the area in the spring of 1960. Because of the failure, fencing of this land will be postponed until the new ley is ready for grazing.

Further areas near the main buildings have been grassed down, and the area surrounding the new administration building will be dealt with as soon as the builders leave the site.

Windbreaks

The windbreak planted along the southern boundary is not proving satisfactory owing to the poor anchorage of the *Cupressus macrocarpa*. Windbreak policy has therefore been reviewed in consultation with Mr. F. W. Shepherd, of the Rosewarne Experimental Horticulture Station, and it has been decided to develop a perimeter shelter belt using *Escallonia* 'Crimson Spire', *Pinus radiata* and *Quercus ilex*. This perimeter belt will be supported internally by a layout of hedges or screens to protect the glasshouses and the outside field trials, using $\times$ *Cupressocyparis leylandii* and/or *Escallonia* 'Crimson Spire'.

Staff

The Nursery Foreman, Mr. T. W. Syer, left to take up a new appointment with the Cheshunt Parks Department in November, after 33 years' service with the Experimental and Research Station at Cheshunt and the Institute. He will be remembered for his kindly nature, and the good wishes of all staff go with him in his new appointment. Mr. L. Toms, who has been a member of the nursery staff since the Institute started, has been appointed to succeed him. Mr. R. F. Potter was engaged for work in the research glasshouses.

II. GENERAL REVIEW OF RESEARCH WORK

1. PLANT BREEDING

by

L. A. DARBY

Tomato

F_5 progenies derived from crosses of 'Baby Lea' and varieties with high quality fruit were grown in replicated trials. All plants were green-stem/compact habit, and many families produced a high percentage of fruit with optimum size, shape and colour. Early and total crop weights compared favourably with the control variety 'Baby Lea'. Small observation trials on these compact-habit selections were also conducted at Experimental Horticulture Stations and at selected commercial nurseries. At the Fernhurst Research Station, where Mr. G. D. Lockie has had considerable experience of managing this type of plant, plots of fourteen different families were grown and these yielded between $14\frac{1}{4}$ and $17\frac{1}{2}$ lb. per plant.

Some families derived from the cross 'Baby Lea' × 'E.S.5' yield very attractive fruit which are extremely firm. Other lines produce the early maturing fruit which is characteristic of 'Harbinger', or the even-ripening fruit of 'Moneymaker' with its freedom from green-back. Progenies from the cross 'Baby Lea' × 'Potential' retain the slow-ripening characteristic of the latter variety.

The influence of the second parent can also be seen in the vegetative growth of plants in the different families. Whilst all are compact-habit with shorter internodes, shorter reflexed leaves and with the trusses closer together, plants derived from 'Baby Lea' × 'E.S.5' are stronger growing than plants derived from 'Baby Lea' × 'Moneymaker'. This presumably reflects the difference between the growth of the parental varieties, as 'E.S.5' is much more vigorous than 'Moneymaker'. The expression of the "recessive determinant" for compact-habit appears to be considerably influenced by the genetic background in which it is functioning. Crosses were made between 'Baby Lea' and several genetic marker stocks carrying alleles for green-stem or dwarf in order to investigate the mechanism which determines the green-stem/compact-habit complex in this variety and its derivatives.

Replicated trials in 1959 have suggested some advantages of small-fruited varieties for early crops. Trial 1 contained 36 commercial varieties and new F_1 hybrids; trial 2, mentioned above, included 36 compact-habit families. Sowing was on 8th December, 1958, planting on 18th February, 1959, and all varieties averaged about 1 lb. per plant picked in April. Data recorded at each harvest for each plot included the total weight of fruit, and the numbers of fruit in each of 42 grades based on standards for fruit size, shape and colour, and their interactions. This allows comparisons to be made, between varieties, of crop weight, mean fruit weight, and the percentage of fruit, by numbers, of various qualities.

Small-fruited varieties matured quicker than larger-fruited varieties, and in general the varieties with the heaviest early (first four weeks) crop achieved it by means of a larger number of smaller fruit. The small-fruited varieties also gave a higher percentage of round fruit and a lower percentage of fruit showing "blotch" symptoms (non-uniformly coloured fruit grades B, C & D as defined in 1956 Annual Report, page 47).

The breeding projects outlined in 1957 have been continued through further generations, and in several of the back-cross programmes plants are now closely resembling the recurrent parent.

Cucumber

Further inbred generations were produced from existing commercial varieties, and the breeding programmes which were described in the 1957 Report continued. One replicated trial of twenty genotypes, including commercial varieties, new F_1 hybrids and inbred lines, was conducted. The experimental results will be published elsewhere. The total crop which was harvested from 500 plants in the period 24th February until 19th June comprised 23,788 fruits weighing 318,073 oz.

Lettuce

Large F_2 families from crosses of 'Cheshunt 5B' with lighter coloured varieties were grown during the winter at the Institute, and also at the N.A.A.S. Experimental Horticulture Station, Fairfield, Lancashire. An attempt was made to select the light green segregants when pricking off and planting out, though this was often difficult with seedlings in bright sunshine. In general, dark green plants were larger and hearted a little quicker than the light green types, though the latter had a more attractive colour. Selections were made and F_3 seed produced.

R_2 families derived from irradiated 'Cheshunt 5B' were also grown. Most of these families grew and hearted up as the control, untreated 'Cheshunt 5B'. A few families contained various proportions of pale seedlings but these were either slow growing or quite unthrifty. One family segregated for dark green/pale green to give a 3:1 ratio.

2. PLANT PHYSIOLOGY

by

E. R. LEONARD

The special purpose glasshouse for the Plant Physiology Department was not fully functional by the end of the year. Tests with the automatic ventilating system have continued. A recording controller, giving proportional-integral control has been obtained for trial. This has been used with copper-constantan thermocouples as sensing element and a feed-back rheostat attached to one of the ventilators. With an open-to-close operation time of the ventilators of one to two minutes this has given good temperature control, without excessive ventilator movement, under different external environmental conditions. However, defects have developed in the motors, in the shaft couplings and in the structure of the ridge ventilators, and are awaiting attention.

The same thermocouples and recording controller, but using on-off switching only, have been used in conjunction with the heating system (high-speed hot water from a calorifier heated by low pressure steam via a motorized valve) and considerable reduction in "hunting" achieved compared with the rod-type bi-metallic thermostat previously installed.

A rotary water meter with electric bell-ringing attachment has been found useful in delivering a fixed quantity of water to experimental plots. A rotary piston meter with variable delivery coupled to a solenoid valve is now being used for the same purpose.

Environmental observations (H. R. B. Hack)

Computation of data on tensiometer variability and growth measurements collected during several past years has been undertaken by the Statistics Department at Rothamsted using the electronic computer.

Performance tests have been carried out on two new potentiometer recorders, one designed for air movement and the other for humidity and temperature recording.

Preliminary observations on plant temperature have been made. Fruit temperatures in the sun were observed similar to those used in the localised heating experiments on "blotchy ripening" initiated in 1958.

A study has been made of the accuracy obtainable in the integration of solar radiation by the methods outlined in the Annual Report for 1958. Data from two solarimeters placed side by side, thus integrating radiation which might fall on different parts of a plant, have been analysed. It is concluded that the accuracy of integration of radiation within a glasshouse is satisfactory in view of the variability in space and time due to changing shade patterns caused by structural members (glazing bars, etc.). Differences between the two instruments in estimating integrated radiation in periods of ten minutes and in accumulated periods over a whole day, were examined.

Growth analysis of the tomato in relation to time of year (A. J. Cooper)

The long term growth analysis experiment on the effect of time of year in relation to the age of the plant on the growth of the different organs was concluded in June. The large volume of data collected is in process of analysis, and publications are being prepared on the growth trends.

A further experiment using five sowing dates at twenty-day intervals from October 28th, 1958 to January 15th, 1959, was carried out, with and without root restriction by whalehide pots, to determine the effect on yield and quality of fruit. This was in collaboration with the Nursery Manager, Mr. J. M. Evans.

The observations on growth in different latitudes have been extended further north and south at additional centres in Finland and Malta respectively. Two growth criteria were recorded.

"Blotchy ripening" (A. J. Cooper and E. R. Leonard)

Further computation of data on environmental conditions and coloration grades of tomato fruit has been undertaken on the electronic computer of the Rothamsted Statistics Department.

The scheme of colour grading for tomato fruit, evolved by Dr. Cooper in 1956 to assist in elucidating the various types of malpigmentation and described in the Annual Report for that year, has been tried out by most of the N.A.A.S. Experimental Horticulture Stations and by the N.I.A.E. Assistants from these Stations met at the Institute in April, and, with the help of Mr. Darby, Plant Breeder, were given a demonstration of the colour standards adopted.

A trial of the effect of different glasshouse environments on the production of fruit pigmentation was sponsored at the Lee Valley Experimental Horticulture Sub-Station at Hoddesdon in collaboration with its then Director, Mr. E. Skillman, and carried out by his successor, Mr. R. Gardner. This involved the use of two separate vinery-type glasshouses with independent heating and ventilating schedules, facilities unfortunately not available at the Institute. One house was maintained at "low", the other at "high" day temperature after setting of the first truss, by adjustment of ventilators, night temperatures being the same in the two houses. Shading was applied to the northern half of each house on the same date. Two watering treatments and two varieties were used. The experiment will require repetition for at least two years under different seasonal conditions before definite conclusions can be drawn.

3. CHEMISTRY

by

G. W. WINSOR

Investigations during 1959 have again been primarily concerned with the nutrition of glasshouse crops and the composition and biochemistry of tomato fruit.

The nutritional studies in progress during 1959 included four experiments with tomatoes, two of which were concerned with fertilizers applied in solution, a factorial experiment with two varieties of carnation, and experiments on winter lettuce.

Studies on the composition of tomato fruit have included both the use of specialized techniques for the separation and determination of individual organic acids and the application of rapid routine procedures for the assessment of fruit quality. The experience acquired during recent years in the interpretation of routine analytical data for tomato fruit, with particular reference to acidity and sugar-content, now makes it worth-while to examine fruit from any experiment in which the visual grading of tomatoes is significantly affected by the factors under investigation.

Studies on the pectic enzymes in tomato fruit have been continued with particular reference to normal and abnormal ripening. Interesting differences have been shown in the pectin methylesterase activity and the proportion of soluble pectic substances in "normal" and "blotchy" areas of tomatoes; the biochemistry of fruit ripening is, however, a very wide subject in relation to the staff and facilities at present available.

Studies of soil salinity and of improved techniques for its assessment have largely centred on soil saturation pastes, and on the examination and development of robust types of conductivity electrode free from the difficulties normally associated with polarization and mechanical weakness.

The symptoms of manganese toxicity have been studied in relation to the manganese content of glasshouse tomatoes and lettuce, using both naturally occurring examples of the disorder and plants treated with excess manganese salts. An extensive programme of analytical work is also in progress, relating the manganese content of plant samples to manurial levels and soil acidity in the factorial nutritional trials.

The main developments in mushroom research have been the construction of equipment for studies of mushroom growth under controlled environmental conditions, and preliminary work on the measurement of moisture stress in casing materials and composts. The need for experimental data on moisture stress arises from previous studies on the relation between salinity and fruiting, and it is also expected that the technique may have interesting applications to present studies of salinity in glasshouse soils.

The extensive duties associated with the conduct of the nutritional experiments have provided opportunities for co-operative study in which almost every member of the Department has taken part. The advantages of this unified approach have been readily apparent during the year, including provision for the fruit composition studies of regular samples grown under a wide range of defined nutrient levels, and the availability of several hundred prepared samples of plant tissue from three major glasshouse crops for studies of manganese toxicity in relation to soil nutrient status. At the same time the data obtained on the acidity and sugar content of tomato fruit have contributed considerably to the value of the nutritional studies, whilst interpretation of the manurial trials with lettuce would have been impossible without consideration of the problem of manganese toxicity and of its relation to soil nutrient status.

Manurial trials with glasshouse crops (G. W. Winsor, M.I.E. Long, and J. N. Davies)

The programme of nutritional studies on tomatoes and carnations has been continued on the lines indicated in the previous Annual Report. The two experiments on liquid feeding of tomatoes (houses C3 and C4) entered the third and final year in their present form, and will be replaced by further trials commencing in 1960. The comprehensive manurial trial in Block B, in which solid fertilizers are used, reached its second season unchanged in form. The magnesium deficiency studies in houses D1 and D2 reached their third successive season; in contrast to experience in previous years, however, an obvious improvement in crop yields resulted from the application of magnesium salts at the "high" level of potash. The trial is to be continued on a reduced scale (house D1 only) in order to gain further information in subsequent years.

The first of a series of trials on carnation nutrition was commenced in July, 1958, and continued unchanged during 1959. The second phase of these trials is planned to start in 1960.

Nutritional studies were extended in 1959 to include winter lettuce under glass, using the 72-plot factorial layout of Block B after clearing the tomato crop. The lettuce proved far more responsive to manurial levels than had been foreseen, and the results justify continued study in subsequent years.

As a background to these nutritional studies of 1959 it may be noted that the soil in Block B and in houses C3 and C4 was steamed for the first time since cropping began in 1954, resulting in higher yields and an obvious improvement in the appearance of the tomato crop. In retrospect it is now obvious that this steaming was long overdue, although it also resulted in excessive uptake of manganese by the plants.

Three integrating photometers were installed in Block B as a guide to watering. An appreciable shift in the calibration of the new photocells became apparent during this first season, however, and watering was accordingly based in part on solarimeter readings kindly supplied from Efford Experimental Horticulture Station.

The simplified scheme of visual grading of tomato fruit from the manurial trials, quoted in the 1958 Report, was again used and is reproduced here for convenience in assessing the current results:

Grade A. Fruit of uniform colour and shape.

Grade B. Fruit of uniform colour but of rather less regular shape than grade A.

Grade C. Fruit showing irregular coloration of any kind, sub-divided on the basis of severity into:

- Sub-grade 1. Slight to moderate severity.
- Sub-grade 2. Severely affected.

Grade D. Any fruit not included in grades A–C, primarily consisting of fruit of highly irregular shape.

It will be seen that grade A corresponds to the "Pink", "White" and "Pink and White" categories of the Tomato and Cucumber Marketing Board, together with a very small proportion of undersized, but otherwise perfect, fruit. Similarly grade B corresponds to the "Blue" and "Blue and White" categories, again together with a minor proportion of smaller fruit of similar shape and colour. Information on mean fruit size has been obtained by recording both weights and numbers of fruit from each plot. It is realised that grade C gives no information on the different types of irregular pigmentation encountered. In order to gain basic information on the forms, position and severity of different types of ripening disorder as a basis for revised grading schemes, a detailed sub-classification of grade C fruit was undertaken at intervals throughout the season; the results of this study are summarized in a separate article (page 83).

Plans are being drawn up to broaden the basis of nutritional studies with horticultural crops still further by the inclusion of chrysanthemums in 1960, and close contact is also being maintained with bulb nutrition studies in sand culture at the Kirton Experimental Husbandry Farm in Lincolnshire.

$3^2 \times 2^3$ factorial nutritional trial with tomatoes (Block B)

The object of this long-term experiment is to study the main effects and interactions of four macro-nutrients, each at two levels of liming, on a more extensive scale than has hitherto been possible. The trials were started in 1958, and a description of the plots and their sub-division by brick walls, together with the previous history of the houses and the fertilizer dressings during 1958, is given in the Annual Report for that year.

The levels of fertilizer applied during 1959 were lower than in the previous year in that no nutrients were added in the second spit. The amount of ground chalk applied in the top spit was also halved, but the applications of nitrogen and potash in the top spit remained unchanged, the total quantities for the season, split between base and top dressings, being as follows:—

Nitrogen	*N1*	Nil
	N2	0.75 oz. nitrogen per sq. yd.
	N3	2.25 oz. nitrogen per sq. yd.
Potassium	*K1*	Nil
	K2	6 oz. sulphate of potash per sq. yd.
	K3	12 oz. sulphate of potash per sq. yd.
Magnesium	*Mg1*	Nil
	Mg2	14 oz. magnesium sulphate per sq. yd.
Lime	*Ca1*	Nil
	Ca2	1 lb. ground chalk per sq. yd.

Each plot contained 16 plants of the variety 'Potentate', set out in the houses on March 14th. The soil in this block of houses had been steamed for the first time since the nursery was built, and more vigorous growth resulted. As in the previous season, an obvious response to phosphate was apparent in the early stages of growth, followed by marked differences between plants growing at the different levels of nitrogen. Symptoms of potassium deficiency were far more prominent among the K1 plots than during 1958, though almost exclusively confined to the K1P2 combination of treatments. Magnesium deficiency symptoms were not entirely eliminated by dressings of magnesium sulphate applied to the soil, even in the second year of the trial. A new feature, almost certainly due to steam sterilization of the soil, was the occurrence of visual symptoms of manganese toxicity, affecting the leaves, petioles and main stems; the symptoms were mainly associated with high nitrogen levels (N3) in combination with low phosphate (P1) and lime (Cal). Measurements of the height of every plant were made in June, an interesting correlation between height and total crop yield having been noted in 1958.

Soil samples were taken for analysis from all plots on three occasions during the season. The mean analytical data for samples taken in June were as follows:

Potassium levels	*K1*	*K2*	*K3*
"Available" potash (K_2O)	0.007%	0.041%	0.091%
Phosphorus levels	*P1*	*P2*	
"Available" phosphate (P_2O_5)	0.006%	0.042%	
Nitrogen levels	*N1*	*N2*	*N3*
Nitrate-nitrogen	5 p.p.m.	27 p.p.m.	105 p.p.m.
Liming levels	*Ca1*	*Ca2*	
*p*H	6.0	7.2	

The mean yields of ripened fruit ranged from 7.2 to 13.2 lb. per plant according to the treatments applied. The main effects of the treatments on crop yield (lb. per plant) are shown in the following data; values for nitrogen and potash are each based on 24 plots, the remaining values on 36 plots:

N1	8.30		*K1*	8.33	
N2	9.77		*K2*	9.82	
N3	9.85		*K3*	9.77	
Mg1	9.26	*P1*	8.74	*Ca1*	9.53
Mg2	9.36	*P2*	9.88	*Ca2*	9.08

It must be emphasised that these are mean values, including both favourable and unfavourable combinations of treatments, and hence do not represent the maximum yields attainable at a given level of any one factor.

As in the preceding year of the trial, phosphate increased crop yields whereas liming depressed them. In contrast to the previous year, however, crop yields increased markedly from the N1 to the N2 level of nitrogen, and from the K1 to the K2 level of potash; this result is almost certainly associated with the more vigorous growth obtained in steamed soil.

The results obtained for the visual grading of the crop in relation to manurial treatments have been sent to Rothamsted for statistical analysis. Discussion of the full data for fruit quality must therefore be deferred, but no statistics are needed to show that fertilizer levels, particularly of potash, markedly affected the grading of the fruit; the results ranged from 3 to 80% of the crop graded as of uniform colour and reasonable shape, and from 18 to 94% showing irregular colour in any form.

In view of the obvious differences in fruit quality arising from the different manurial treatments, the composition of fruit from all 72 plots was studied on three occasions during the season; the results are referred to in a separate section of this report. Samples of foliage were also collected from all plots on two occasions, and are now being analyzed.

The effects of nutrient concentration in liquid feeds on crop yields and fruit quality of tomatoes (*House C3*)

This trial, the layout of which was described in the Annual Report for 1957, entered on the third and final season in 1959. As in previous years a nutrient solution containing nitrogen and potash ($K_2O/N = 1.75$) was applied at four different concentrations, each treatment being replicated four times. Phosphate was applied uniformly throughout as a base dressing only. The concentration of nutrients in the liquid feed, used throughout the season at all waterings, was as follows:

	Nitrogen	*Potash* (K_2O)
Treatment A	75 p.p.m.	131 p.p.m.
,, B	150 p.p.m.	263 p.p.m.
,, C	225 p.p.m.	394 p.p.m.
,, D	300 p.p.m.	525 p.p.m.

Application was by hose watering through an automatic pump-operated dilution system. The variety of tomato planted was 'Potentate', as in 1958. The soil in this house had been steamed for the first time, resulting in a notable improvement in growth as compared with the previous year. The nutrient levels were designed to cover a range of concentrations of practical importance over and above the minimal requirements for reasonable growth. Apart from a very slightly

paler green in the foliage of plants receiving the lowest nutrient concentrations, little or no difference was noted in vegetative growth, and no symptoms of nitrogen or potash deficiency occurred. Magnesium deficiency increased in severity with nutrient concentration, however, as also did the effects of manganese toxicity. Soil samples were taken for analysis from all plots on three occasions during the season, together with two complete sets of leaf samples.

The total fruit yields and their visual grading are summarized in Table I.

TABLE 1

THE YIELD AND GRADING OF FRUIT FROM PLANTS GROWN AT DIFFERENT NUTRIENT CONCENTRATIONS IN THE LIQUID FEED

Treatment	Concentration (*p.p.m.*) in diluted feed		Total yield (*lb/plant*)	Grading of fruit (%)		
	Nitrogen	Potash (K_2O)		A+B	C1+C2	C2
A	75	131	10.9	46.4	48.2	4.1
B	150	263	10.6	57.9	37.0	1.5
C	225	394	10.3	61.7	31.1	0.9
D	300	525	10.2	64.2	29.9	0.5

The results show a small decrease in total crop yield with increasing nutrient concentration, accompanied by an increase in the proportion of fruit showing uniform colour and reasonably regular shape (grades A and B). The total yields of fruit in grades A and B increased by over 1 lb. per plant from treatment A to B, with further small increases up to the highest concentration. In practice it would seem that nutrient concentrations at or slightly below those of treatment C would be sufficient to obtain most of the benefits in fruit quality which can be gained by this means. Even at the highest nutrient concentration nearly 30% of the crop was graded as of irregular colour; it must be emphasized, however, that a proportion of this category would still have been acceptable by commercial standards. The amounts of very severely affected fruit (grade C2) were relatively low.

A full account covering the three years of this trial will be presented in due course.

Studies on potash/nitrogen ratio in nutrient solutions (*House C4*)

Studies on the liquid feeding of tomatoes, using trickle irrigation equipment, were started in this house in 1957; the experiment reached its third and final season in 1959. The object of the trial is to compare the yields and fruit quality of tomatoes grown with liquid feeds having four different potash/nitrogen ratios (K_2O/N), the ratios selected being 1.0:1, 1.5:1, 2.0:1, and 2.5:1. Details of the experimental layout were given in the Annual Report for 1957 and need not be repeated here. The treatments are replicated six times, and occupy a house measuring 110 ft. x 14 ft.

The tomato plants (variety:'Potentate') were set out in the borders on March 6th. The concentration of nitrogen in all nutrient solutions was 225 p.p.m. initially, being reduced to 175 p.p.m. at the end of April and subsequently maintained at that level throughout the season. A total of 35.6 gallons of diluted nutrient solution was applied per plant during the season.

Records of the incidence and severity of magnesium deficiency symptoms show that the degree of chlorosis was lowest at a potash/nitrogen ratio of 1:1, and increased somewhat with the concentration of potash in the nutrient solution.

Fruit from each of the experimental plots was recorded separately throughout the season until 28th September. The total yields per plant and the visual grading of the fruit are summarized in Table II.

TABLE II

THE YIELD AND GRADING OF FRUIT FROM PLANTS GROWN WITH LIQUID FEEDS HAVING DIFFERENT POTASH/NITROGEN RATIOS

Treatment	Total yield (*lb/plant*)	Grading of fruit (%)		
		A+B	C1+C2	C2
K_2O/N =1.0	11.8	39.5	54.9	7.7
,, =1.5	11.7	45.1	49.4	6.1
,, =2.0	11.8	51.3	43.6	3.9
,, =2.5	11.6	53.6	40.7	3.6

The results show that as the potash/nitrogen ratio in the liquid feed increased there was an increase in the proportion of fruit of uniform colour and reasonably regular shape (grades A and B), with an accompanying decrease in the proportion of irregularly coloured fruit. The total crop yields were satisfactory (71 tons per acre), and the fall in yield with increasing potash concentration was very slight.

As in previous years, planting in rows along the house showed up marked positional differences in cropping. Thus the four plots (single-line planting) along the west side of the house (which is also the west edge of the block of four houses) averaged 16.9 lb. per plant.

Soil samples were taken at the end of the season to confirm the distribution of nutrients at and between nozzles in the trickle system. Studies of total nutrient uptake were also continued on 24 plants as in previous seasons.

Magnesium in the nutrition of glasshouse tomatoes (*Houses D1 and D2*)

An experiment on magnesium deficiency in tomato plants, started in 1957, has now completed its third successive season. The purpose of this trial is to study the effects of magnesium sulphate, applied to the soil or to the foliage, on (*i*) visual symptoms of magnesium deficiency, (*ii*) uptake of magnesium by the plants, (*iii*) crop yields and (*iv*) fruit quality. The experiment also includes two levels of potash in the soil in order to provide data on the interaction of magnesium and potassium in the nutrition of the crop. The full range of treatments is as follows:

Treatment	*Potash*	*Magnesium*
A	"Low"	None added
B	"Low"	Soil application
C	"Low"	Foliar spray
D	"High"	None added
E	"High"	Soil application
F	"High"	Foliar spray

The six treatments are each replicated six times, and each plot contains two varieties of tomato ('Potentate' and 'Immuna'). The general layout of the trial was given in the Annual Report for 1957.

The plants were set out in the borders on 4th March, the soil having been steamed in January. Day temperatures in the house were somewhat higher than in previous years, and the spacing between trusses became rather excessive. Some of the "low potash" plots showed traces of marginal chlorosis in May, typical of potassium deficiency, but the symptoms largely disappeared as the season progressed.

Chlorosis due to magnesium deficiency became prominent in June on the foliage of plants not receiving magnesium sulphate, particularly on the variety 'Immuna'. This chlorosis was largely controlled by applications of magnesium sulphate either to the soil or to the foliage, particularly at the lower level of potash. The most severely affected plots were those receiving no added magnesium at the "high" potash level; plants of the variety 'Potentate' in these plots showed not only a severe chlorosis but much marginal brown necrosis, and the tops of the plants became very weak and in some cases even died.

The mean yields of ripened fruit (lb. per plant), uncorrected for plants lost during the season, were as follows:—

Variety	*Treatment*					
	A	*B*	*C*	*D*	*E*	*F*
'Potentate'	8.8	9.1	8.7	8.0	10.3	9.5
'Immuna'	10.4	10.6	10.3	9.8	11.3	11.1

The highest yields were obtained where magnesium sulphate was applied (treatments E and F), and the lowest where magnesium was omitted (treatment D), at the "high" level of potash. 'Immuna' again gave higher yields and a lower proportion of irregularly coloured fruit than did 'Potentate', thus confirming the results obtained in the two previous seasons. The crop records have been sent to Rothamsted for statistical examination, and detailed discussion must therefore be deferred. It is, however, obvious that a marked response in total yields has resulted in 1959 from the correction of magnesium deficiency at the "high" potash level, in contrast to the two preceding years of the trial. Whether this result was due to the abnormally bright summer weather during 1959, or to the somewhat changed growing conditions, is not yet known; whatever the cause, it is apparent that conditions can arise which make treatment with magnesium salts worthwhile. The trial will be continued on a reduced scale (house D1 only) from 1960 onwards.

3 x 2^4 factorial nutritional trial with carnations (House E2)

A preliminary experiment on the nutrition of glasshouse carnations was commenced in 1958, and has continued throughout 1959. This experiment was designed to show the effects of nitrogen at three levels of application (25, 125 and 225 p.p.m.) and of potash at two levels (50 and 175 p.p.m. K_2O), both supplied entirely in nutrient solutions and superimposed on two levels of phosphate, magnesium and lime (carbonate) in the beds. The construction and layout of the concrete beds, and of the trickle irrigation system, were outlined in the Annual Report for 1958. There are 48 experimental plots, each containing 30 plants of both 'Improved William Sim' and 'Saugus White', in addition to guard rows of 'Crowley's Pink Sim'.

It was originally intended that all the water applied to the plots should contain nitrogen and potash at the stated concentrations, applied via the trickle irrigation system. In practice, however, it was found desirable to give limited additional amounts of water by hose along the outer edges of the beds, the quantities used being metered separately for each plot.

Studies on the nutrition of the carnation have been very limited in the past, and little guidance as to nutrient levels was available when laying down the present trial. Some analytical work on soil and tissue samples remains to be done, but it would appear that a reasonable range of values for nitrate and potash has been achieved in this exploratory work. Somewhat surprisingly, however, the quantity of very finely divided chalk (15 lb. per cubic yard of compost) incorporated prior to filling the beds has proved insufficient to maintain *p*H values above *p*H 7 in plots receiving both lime and phosphate; lower levels of phosphate, supplemented if necessary by top-dressings, should allow a clearer pattern of *p*H values in relation to liming in the next series of trials.

The appearance of the plants was carefully examined at intervals for signs of nutrient deficiency or toxicity. Tip-burn of the leaves of variety 'Saugus White', recorded on all plots receiving the high level of phosphate, was described in the previous report and was later shown to be associated with a high level of manganese in the foliage; 'William Sim' was unaffected. Plants of variety 'Saugus White' in most of the plots receiving inadequate potash (K1) but adequate levels of nitrogen (N2 or N3) and phosphate (P2) have since shown a pale browning of the leaf tips, and some chlorosis affecting mature leaves of 'William Sim' has been recorded from the same combination of treatments; the results suggest potassium deficiency, but confirmation or otherwise is awaited from tissue analyses now in progress. The effects of nitrogen deficiency can be seen among plants receiving the lowest level of nitrogen in the liquid feeds, and include not only the loss of colour in the foliage, but also, during the winter months, more pronounced symptoms of "curly top" as described by Messing (10). Growth in the presence of added phosphate appears sturdier than in its absence where the levels of the other nutrients are not limiting, but quantitative data on this point will not be obtained until the plants are removed at the end of the trial in 1960.

Records of the total number of blooms cut up to November 5th, 1959, show a 21% increase due to phosphate for the variety 'William Sim', but no effect for 'Saugus White'. Both varieties show an increase of about 10% in total numbers of blooms at the N2 level as compared with N1. Records for the grading of blooms have not yet been brought up to date, but the data up to August 1959 show considerably more splitting of the calyx at the lowest level of nitrogen, particularly in the variety 'William Sim'.

The mean numbers of blooms per plant cut by November 5th, 1959 (the experiment having been planted on July 24th, 1958), were 25.1 for 'Saugus White' and 19.4 for 'Improved William Sim', although some plots receiving favourable treatment combinations have of course exceeded these figures considerably.

The experiment will continue in the present form until the late summer or early autumn of 1960; experience gained in this preliminary phase is already proving most valuable in the planning of subsequent studies.

$3^2 \times 2^3$ factorial nutritional trial with lettuce (Block B)

At the conclusion of the 1959 tomato season the opportunity was taken to plant a crop of lettuce (variety: 'Cheshunt 5B') in the 72 plots of the long-term manurial trial in Block B. Each plot contained 72 plants under investigation, set out in the borders on September 22nd and 23rd, with additional guard rows adjoining the heating pipes.

On the basis of soil analyses prior to planting it was only found necessary to apply small quantities of nitrogenous fertilizer (hoof and horn) in order to re-establish differential nitrate levels; the levels of phosphate, potash, magnesium and lime remained as at the end of the tomato nutritional trial.

By the end of September differences in size, colour and form were readily apparent, being almost entirely governed by the levels of nitrogen and phosphate. By the second week in October, however, plants in many of the plots developed a marginal scorch of the type previously produced in studies on manganese toxicity. The occurrence of manganese toxicity at first appeared unlikely in soil which had not been steamed since November 1958, but analysis of lettuce plants from the guard rows confirmed that the affected plants in fact contained appreciable quantities of this element.

The lettuce were harvested as they matured, starting on October 26th and finishing on December 3rd, and were graded as "marketable" or "unmarketable". The number and total weight of lettuce in each grade were recorded at each date of cutting. The crop records are being examined by Mr. Cooke of the Statistics Section, with whose collaboration the trial was conducted, and further discussion will be deferred until a later Report. It is evident, however, that the crop was highly responsive to nutrient levels in the soil and to soil *p*H.

Representative samples of lettuce were taken from all 72 plots at comparable stages of maturity during harvesting for the determination both of nutrient content in relation to manurial levels and of manganese content in relation to visual symptoms of marginal necrosis.

As a result of favourable weather conditions in the early weeks of this experiment, it was possible to replant the houses with a further batch of lettuce (variety: 'Cheshunt Early Giant') before Christmas. This second crop had to be pulled out before reaching maturity, owing to the need to start preparations for the succeeding tomato crop, but data were obtained for mean weight per lettuce, based on a sample of 33 lettuce per plot. The results, which again show an obvious response to phosphate and nitrogen, await statistical examination.

Manganese toxicity (D. M. Massey and G. W. Winsor)

The difficulties encountered with test plants grown in sterilized potting mixtures, which hindered progress in the soil salinity programme, ultimately led to studies on manganese toxicity. Coinciding with the increasing use of steam-sterilization in the trial glasshouses, the symptoms of manganese toxicity already noted in sterilized potting mixtures were soon recognised in winter lettuce grown on the main nursery, and were subsequently diagnosed among tomato plants and carnations in the nutritional trials and elsewhere at the Institute. The opportunity was therefore taken to collect tissue and soil samples wherever the symptoms of manganese toxicity occurred, with the ultimate object of compiling sufficient analytical data to indicate the tolerance levels of the various horticultural crops and to allow rapid confirmation of possible toxicity symptoms.

The release of appreciable amounts of soluble and exchangeable manganese on steam sterilization has undoubtedly introduced a further variable into the manurial trials. Thus the occurrence of toxicity symptoms and the manganese content of the foliage of tomato plants grown in the 72-plot factorial nutritional trial in Block B both varied greatly with the fertilizer treatments. Statistical examination of the data will be necessary, however, before it can be established whether or not the levels of nutrients applied influenced the manganese content of the tissue in ways other than by an indirect effect on soil *p*H. The conditions most conducive to the occurrence of manganese toxicity symptoms in this particular trial have been the absence of lime and the liberal use of a potentially acidic nitrogenous fertilizer (ammonium sulphate); a relation between *p*H and manganese toxicity is apparent, as shown in Table III.

TABLE III

MANGANESE CONTENT OF TOMATO FOLIAGE FROM BLOCK B, JULY AND AUGUST 1959, EXPRESSED ON THE BASIS OF OVEN-DRIED TISSUE

Plot	Treatment*						Manganese (*p.p.m.*)
	N	P	K	Mg	Lime	*p*H	
34	2	2	1	1	2	7.2	245
27	2	2	2	1	2	7.1	357
35	3	1	1	1	1	5.5	1,711
51	3	1	2	1	1	5.4	2,195
69	3	1	3	1	1	5.1	2,455

*For details of treatments see report on nutritional trials; the coding 1 indicates omission of this nutrient or material from the fertilizer dressings, whilst 2 and 3 denote increasing levels of application.

The concentrations of manganese in foliage from plots 34 and 27 were in no way excessive for tomatoes, as would be expected at *p*H values above 7. Where lime was omitted and high levels of nitrogen applied, however, as illustrated in the Table by data for plots 35, 51 and 69, far higher levels of manganese resulted in the foliage, and under these conditions the uptake of manganese appeared to increase with the levels of potash applied. Low levels of soil phosphate also tended to increase manganese uptake.

As noted in the section referring to the nutritional trials, manganese toxicity symptoms in Block B were even more widespread in the winter lettuce than in the tomato crop. A full series of 72 samples of lettuce, representing all treatment combinations, is now being analysed for manganese content, but exploratory samples taken from the guard rows at an early stage of growth suffice to show the extent to which manurial treatments influenced plant composition (Table IV).

TABLE IV

MANGANESE CONTENT OF YOUNG LETTUCE PLANTS FROM BLOCK B, OCTOBER 1959

Plot	Treatment*					Manganese (*p.p.m.*)	Toxicity symptoms
	N	P	K	Mg	Lime		
27	2	2	2	1	2	126	None
37	2	1	2	1	2	175	None
52	3	2	1	2	2	350	Moderate
30	3	1	1	2	1	600	Severe
35	3	1	1	1	1	711	Severe
36	3	2	1	2	1	786	Severe

*For details of treatments see report on nutritional trials; the coding 1 indicates omission of this nutrient or material from the fertilizer dressings, whilst 2 and 3 denote increasing levels of application.

Lettuce grown in limed plots without excessive nitrogenous dressings were generally free from toxicity symptoms and had a low content of manganese, but high nitrogen levels, particularly in the absence of lime, resulted in obvious symptoms of manganese toxicity and a high uptake of this nutrient. As was previously noted for tomatoes, a general relation appears to exist between soil *p*H and the manganese content of the tissue.

The manganese content of carnation plants is being studied in relation to nutrient levels in the manurial trials in house E2. As noted in the Annual Report for 1958, a considerable degree of tip-burn occurred in the variety 'Saugus White' within two to three months of planting out in the steam-sterilized compost; the symptoms were later shown by analysis to coincide with a high content of manganese in the affected tissue. The toxicity symptoms were confined to the early stages of growth, however, and did not continue to develop through the life of the crop; the effect is thought to be related to the somewhat low initial *p*H values in the compost under certain combinations of nutritional treatments.

Among various other samples examined for manganese content, some of the highest values encountered in the foliage of glasshouse tomatoes were for samples from the Lee Valley Experimental Horticulture Station at Hoddesdon; eight samples of foliage from this centre gave values ranging from 2110 to 3850 p.p.m. manganese on the basis of oven-dried tissue, the mean value being 2850 p.p.m.

Apart from studies on the manganese content of plants in relation to naturally-occurring symptoms of toxicity, the condition has also been produced experimentally in both tomato and lettuce plants by treatment with manganese salts. Descriptions of the toxicity symptoms, which in the tomato can appear in several forms, have been compiled, together with photographic records.

Soluble salts in glasshouse soils (D. M. Massey and G. W. Winsor)

A preliminary report on the various methods available for the determination of soluble salts in glasshouse soils, based on measurements of electrical conductivity, was given in the Annual Report for 1956 (16), it being concluded that the conventional procedure used in this country was unreliable in the presence of high concentrations of calcium sulphate such as are commonly encountered in old glasshouse soils. Staff was not available to continue these studies at the time, and work on the subject was not resumed until late in 1958; as noted in the Annual Report for that year, however, much difficulty was then encountered with the test plants (lettuce) used when attempting to confirm relationships between plant growth and salinity as measured by the various procedures. Whilst a relation between salinity and plant mortality was repeatedly demonstrated, the difficulty was to keep the test plants alive at the higher levels of soluble salts in order to provide sound data for the salinity/growth curves. No less than five series of trials were conducted with lettuce plants before a fully satisfactory experiment was completed in the early autumn of 1959.

The results now obtained confirm the main points established in 1956 (16). The most direct approach to the problem is to work with displaced soil solutions, thus avoiding errors associated with the addition of water to the soil during the test. For technical reasons, however, the widespread use of displaced soil solutions for advisory purposes is unlikely, and the best compromise may prove to be based on soil saturation pastes. It has been decided provisionally to regard conductivity measurements in filtrates prepared from soil saturation pastes (14) as an acceptable general method. Compared with the routine procedures commonly used in this country, which are based on aqueous soil suspensions prepared with a large excess of water, the saturation paste extract technique is undoubtedly time-consuming, and alternative methods are still being examined. Particular attention has been given to electrode systems suitable for direct use in soil saturation pastes; the main problem here at first appeared to be that, whereas the deposits of platinum black on conventional platinum electrodes were easily contaminated and abraded by contact with soil pastes, bright (unplatinized) metal electrodes were prone to appreciable errors due to polarization. With the generous co-operation of Messrs. Wayne-Kerr Ltd., it has been possible to study this

polarization of electrodes, both in soil pastes and in salt solutions as used for the calibration of electrodes, using a conductivity cell in which the spacing between the two electrodes could be controlled accurately by means of a micrometer gauge in conjunction with an advanced type of measuring bridge for simultaneous determination of both conductance and capacity. Electrodes of this type are not suitable for routine testing of soil pastes, however, and attention was next centred on possible materials for the construction of electrodes free from both polarization and mechanical weakness. A novel form of conductivity cell developed for industrial use in pipelines, consisting of electrodes of hard carbon set in the inner surface of an inert plastic tube, appeared to combine both these requirements, the cell constant being virtually independent of concentration and the electrodes being sufficiently robust to be cleaned with a bottle-brush.

The use of carbon electrodes of the type referred to in the preceding paragraph, together with other forms of robust probe-type electrode, was included among the techniques applied to soil samples from the salinity trials with lettuce. Excellent correlations were obtained between conductivity measurements with conventional electrodes in the filtrate from soil saturation pastes and the direct readings with robust electrodes in the soil pastes themselves. The direct measurement of electrical conductivities in soil pastes, having the advantage of eliminating a somewhat difficult filtration of thick muds, thus already appears to provide a useful shortcut to the routine use of saturation pastes within a single soil type, as for example within the nutritional trials at this Institute. Any conclusions regarding the more general application of the method must, however, await extension of the work to a wide range of soil types as distinct from a single soil containing varying levels of fertilisers.

The composition of tomato fruit (J. N. Davies and G. W. Winsor)

Studies on fruit composition have now been an established feature of the Chemistry Department's research programme for several years, and have an obvious bearing on problems of fruit quality. For convenience the work may be classified under two headings:

1. Application of a rapid procedure for the routine examination of large numbers of fruit samples, including determinations of titratable acidity, sugars, total solids and refractive index of the juices expressed from frozen fruit. This scheme of analysis was originally developed in 1954 (G. W. Winsor and D. M. Massey) for studies relating to the problem of "blotchy ripening" (9), and has since been modified to include the use of a hydraulic press for expressing the fruit juices and of a highly sensitive refractometer for the rapid assessment of total solids.
2. Detailed long-term studies on selected components of tomato fruit, started in 1956 (J. N. Davies). Early work was concerned with the chromatographic separation and micro-estimation of individual sugars (3). More recently attention has been directed to a study of the non-volatile acids of the tomato fruit, as referred to in a later section of this Report.

The main subjects investigated by means of the routine analytical procedure during 1959 included:

(a) The composition of tomato fruit in relation to manurial treatment.
(b) Further studies on the effects of shading on fruit quality and composition.
(c) Comparison of the fruit of different varieties of tomato.
(d) Comparison of hormone-set and naturally pollinated tomatoes.
(e) Preliminary studies on the composition of individual fruit in relation to their position on a truss.

(f) Differences in the composition of the outer walls of tomatoes in relation to position on the fruit, this study including both uniformly ripened fruit and fruit showing "hard top" in both its yellow and green forms.

A preliminary study was also made of the differences in acidity and sugar content of two varieties of tomato in relation to physical and cultural factors (temperature, shading and watering), using fruit kindly supplied by the Director of the Lee Valley Experimental Horticulture Station at Hoddesdon; it is hoped to extend this investigation in subsequent years.

Although the range of samples examined has been wide, the main emphasis during 1959 has been on the relation between fruit composition and plant nutrition, this programme being dependent on the existence of extensive manurial trials. The large number of samples involved when studying fruit from the main factorial nutritional trials has made the use of semi-micro analytical methods almost essential, and the new procedures have also proved particularly appropriate for investigations involving the composition of individual fruit or parts of fruit.

Studies of the refractive index of the expressed sap of tomato fruit in relation to the concentration of soluble solids have been continued. The sensitive immersion refractometer with facilities for precise temperature control which was first used in 1958 has again been used in these investigations. A considerable mass of data has accumulated in the last two years, over 600 samples having been examined. Statistical analysis of the data is still incomplete, but it is evident that a very close relation exists between refractometer readings and the total soluble solids as determined by oven-drying, a group of 626 samples giving a correlation coefficient of +0.972, significant at P=0.001.

The composition of tomato fruit (variety: 'Potentate') from the $3^2 \times 2^3$ *factorial nutritional trial (Block B)*

A description of the long term manurial trial with tomatoes, designed to study the main effects and interactions of nitrogen, phosphate, potash and magnesium each at two levels of liming on growth, composition and cropping, is given in another section of this report. During 1959 the analytical programme undertaken in connection with this trial, hitherto limited to nutrient levels in soil and foliage, was extended to include studies of certain organic constituents of the tomato fruit as related to fruit quality. Procedures have been developed for the examination of large numbers of small samples of fruit, based on the use of the hydraulic press and semi-micro analytical methods; these techniques were used in June, July and August, when samples of the best quality fruit available were collected from each of the 72 experimental plots. The titratable acidity and refractive index of the expressed sap were determined on every sample, and the dry matter content of the fruit on samples from the 36 plots which received dressings of magnesium sulphate (Mg 2). A limited number of determinations of the sugar and potassium contents of the expressed sap were also made.

Statistical analysis of the extensive data obtained in this trial is as yet incomplete, but some interesting trends are already apparent. With regard to the titratable acidity of the expressed sap, three out of the five factors included in the trial had significant effects at each of the three sampling dates. Thus potash applied at the "medium" and "high" levels (K2 and K3) increased the acidity of the fruit as compared with the "low" (K1) level, the difference being significant at P=0.001. Similarly, increasing additions of nitrogen were accompanied by significant increases in the titratable acidity of the expressed sap, the effect also being significant at P=0.001. Additions of phosphate had the reverse effect, the acidity of the fruit being reduced. On all three sampling dates a significant interaction with regard to the titratable acidity was found between the nitrogen and potash levels. Mean values for samples taken on 23rd June are given in Table V.

TABLE V

TITRATABLE ACIDITY (MILLIEQUIVALENTS PER 100ML) OF THE EXPRESSED SAP OF FRUIT FROM PLANTS GROWN AT DIFFERENT LEVELS OF NITROGEN AND POTASH

Potash level	Nitrogen levels			Potash level means
	N1	N2	N3	
K1	5.4	5.8	5.9	5.7
K2	6.7	7.8	8.4	7.7
K3	7.0	8.0	8.9	8.0
Nitrogen level means	6.4	7.2	7.7	

The results show that, at the lowest potash level (K1), increasing nitrogen levels had little effect on the titratable acidity of the expressed sap, but at the K2 and K3 levels the increasing nitrogen levels resulted in a marked increase in the acidity of the fruit. As a practical guide to the interpretation of the acidity data in Table V, values for variety 'Potentate' above 7.5—8.0 indicate fruit of good flavour, whereas values below about 6.5 correspond to inferior fruit of insipid taste.

The sugar content of the expressed sap was only determined on fruit from plants grown on the 18 unlimed plots (Cal) which received magnesium sulphate (Mg2). The results, while not so striking as those obtained for fruit acidity, indicate a significant decrease in sugar content with increasing nitrogen levels on all three sampling occasions.

The effect of nutrient concentration in liquid feeds on the composition of tomato fruit (variety : 'Potentate')

Studies of the effect of nutrient concentration on the growth, cropping and fruit quality of tomatoes were started in house C3 during 1957. In this trial a liquid feed containing nitrogen and potash only ($K_2O/N = 1.75$) is applied at four different concentrations throughout the growing season:

	N (*p.p.m.*)	K_2O (*p.p.m.*)
Treatment A	75	131
,, B	150	263
,, C	225	394
,, D	300	525

In each of the three years of the trial the quality of the fruit has increased with nutrient concentration, and during 1959 it was decided to compare the composition of tomatoes from the four treatments.

Samples of the best quality fruit (grade A as defined in the section on manurial trials) available from each of the four treatments were taken for analysis of the expressed sap on ten occasions from June to September; the dry matter content of the fruit was also determined on the last seven sampling dates.

The concentration of nutrients in the liquid feed had a marked effect on some aspects of the composition of the fruit, as shown by mean values for the four treatments in Table VI.

TABLE VI

EFFECT OF NUTRIENT CONCENTRATION IN THE LIQUID FEED ON SOME ASPECTS OF TOMATO FRUIT COMPOSITION

	Treatment				Significant differences between means	
	A	B	C	D	P=0.05	P=0.01
Sugars in the expressed sap (*g/100ml*)	2.80	2.71	2.96	2.89	—	—
Titratable acidity (*milliequivalents/100 ml*)	7.6	8.4	8.9	8.8	0.4	0.6
Total solids (*g/100 ml*)	4.39	4.46	4.84	4.84	0.18	0.24
Dry matter (%)	6.10	6.19	6.51	6.49	0.33	—

Reducing sugars in the expressed sap were little affected by nutrient concentration, but both the titratable acidity and the total solids content of the expressed sap were significantly increased at the higher nutrient concentrations in the liquid feed, as also was the dry matter content of the fruit. The improvement in fruit quality with increasing nutrient concentration, as assessed by visual grading (Table I), was thus accompanied by changes in fruit composition, particularly with regard to acidity.

Some seasonal trends were noted in the composition of the expressed sap. Thus the concentrations of sugars and sap solids rose to a maximum in mid-July, whereas the titratable acidity was reasonably high throughout and showed no pronounced seasonal trends.

The effect of manurial treatments on the composition of tomato fruit of varieties 'Potentate' and 'Immuna'

The effect of manurial treatment on the composition of fruit of these two varieties grown in the trials on magnesium deficiency in houses D1 and D2 was briefly described in the Annual Report for 1958. These studies have been continued and extended to include all six combinations of treatment of each variety. On ten occasions between June and the middle of September a composite sample of fruit of the best quality available from the six replicated plots of each of the following four fertilizer treatments was analysed:

"Low" potash	No magnesium
"Low" potash	Magnesium as foliar spray
"High" potash	No magnesium
"High" potash	Magnesium as foliar spray

On the last four sampling dates fruit from the other two treatments, in which magnesium sulphate is applied to the soil at both "low" and "high" potash levels, was also analysed.

With regard to potash the results were similar to those found in 1958. Thus the effect of "high" as compared to "low" potash was to increase the mean value for the titratable acidity of the expressed sap from 6.5 to 7.7 milliequivalents per 100 ml. in the case of 'Potentate' and from 7.5 to 9.0 for 'Immuna', the differences being significant at P=0.001 in both cases. The differences were again reflected in the data for total solids in the sap; the sugar content, however, was unaffected by the potash levels. The differences in titratable acidity were more pronounced than those found in 1958, probably as a result of the continued depletion of the reserves of potash in the "low" potash plots, and were accompanied by marked differences in fruit quality as assessed by visual grading.

In 1958 the application of foliar sprays containing magnesium sulphate had no significant effect on the acidity of the fruit of either variety. The results obtained in 1959 again show no overall effect of foliar sprays on fruit acidity when assessed over the whole season from June to September. Samples taken in the later part of the year do, however, show some response to treatment with magnesium sulphate. Thus statistical analysis of the data for all six combinations of fertilizer treatment at the last four dates of sampling (twice in August and twice in September) shows a significant increase in fruit acidity resulting from foliar sprays applied to the variety 'Immuna' at the "low" potash level as well as for the variety 'Potentate' at the "high" level of potash, both effects being significant at $P=0.01$.

Application of foliar sprays containing magnesium to the variety 'Immuna' resulted in a significant increase in the sugar and total solids content of the expressed sap at the lower level of potash, but had no effect at the higher level of soil potash; no significant effects were observed with the variety 'Potentate'.

The results of previous comparisons of the composition of fruit of the two varieties in 1957 and 1958 are confirmed by the present study. Thus fruit of the variety 'Immuna' was again more acid than that of 'Potentate', whereas the mean values for sugar content showed little difference between the two varieties.

The effect of shading on fruit composition

A study of the effect of shading on the composition of tomato fruit (variety: 'Potentate') was described in the Annual Report for 1958. Shading was provided for pot-grown plants by frameworks of wooden laths. This investigation has been continued with the variety 'Potentate' and also with the more acid variety 'Ailsa Craig'. It has also been extended to include the effect of slight shading provided by curtain net supported on a frame of bamboo canes. Two similar experiments were carried out, in one of which fruit was harvested in early summer (May to July) and the other in early autumn (September to October).

The main effects of shading on the composition of the expressed sap observed in the first year of the experiment have been confirmed. Thus sugars and total solids in the expressed sap of both varieties were reduced by shading. The acidity of the fruit of variety 'Potentate' was again higher for the shaded than for the unshaded plants. With variety 'Ailsa Craig' no significant difference was found in the acidity of fruit from shaded and exposed plants in the first of the two series of experiments. Later in the year, however, shading produced a significant increase in the acidity of the expressed sap of this variety also.

The adverse effect of shading on fruit yield was again demonstrated. Thus in one experiment with the variety 'Potentate' the mean yields of fruit per plant, obtained from four trusses, were 2,864, 2,551 and 1,357g. in the exposed, lightly shaded and heavily shaded series respectively. Extensive crop records were maintained during these experiments, and non-uniformly coloured fruit were subdivided into numerous categories in an attempt to clarify the observations made during 1958. The favourable influence of shading on the proportion of uniformly pigmented fruit was again observed, although the effect was not so pronounced with the variety 'Potentate' as in the previous year. A large proportion of the fruit from plants of both varieties exposed to full sunlight showed hard yellow or yellow-orange areas around the calyx, an effect previously observed in 1958; this disorder is the yellow form of "hard-top" or "greenback" as referred to in a separate article on fruit grading elsewhere in this Report. The heavier degree of shading again markedly decreased the incidence of this disorder, but the lighter shading achieved with curtain net was less effective.

The results obtained in 1958 gave some indication that shading, in direct contrast to its effect on "greenback", had also led to some increase in the proportion of "blotchy" fruit. The high proportion of fruit showing "greenback" on the fully exposed plants, however, makes it essential to distinguish with the utmost care between "greenback" and "blotchy ripening", it being noted that the latter defect commonly includes areas adjacent to the calyx. During 1959 a more detailed grading scheme was used in which "blotchy ripening" at two levels of severity was sub-classified by position as "top" or "side", both alone and in combination with "hard-top". The results for both varieties and in both experiments during 1959 clearly show that the proportion of the total crop graded as "blotchy" was increased by shading; furthermore it was found that, for the variety 'Ailsa Craig' though not for 'Potentate', the actual weights of "blotchy" fruit per plant were increased by heavy shading despite the marked reduction in total yields.

The composition of fruit of different varieties of tomato

The following seven varieties were grown in houses C1 and C2 in a soil sterilization trial undertaken by the Crop Protection Department:—

A. 'Potentate'
B. 'Ailsa Crag'
C. 'Moneymaker'
D. 'E.S.5'
E. 'L.M.R.1'
F. 'Delicious'
G. 'Radio'

Samples of the best quality fruit available from each variety were obtained on twelve occasions between early June and late September for analysis of the expressed sap. With the exception of the first date of sampling the dry matter content of the fruit was also determined, and on six occasions additional samples were preserved in alcohol for the determination of sugars and acids.

Statistical analysis of the data for titratable acidity of the expressed sap showed highly significant differences between the varieties studied. Mean values ranged from 7.1 milliequivalents of acid/100 ml. sap for the variety 'Moneymaker' to 9.5 for 'L.M.R.1'. It may be noted that 'L.M.R.1' was also the most acid variety in the 1958 studies, and gave the highest acidity/sugar ratio in both years.

The highest content of sugars and total solids in the expressed sap was shown by fruit of the varieties 'Radio' and 'L.M.R.1'. The range of variation observed in these two tests, however, was considerably narrower than that found in the previous year's trial as described in the Annual Report for 1958. Thus mean values for sugars ranged from 2.76 to 3.09 g./100 ml. sap and total solids from 4.40 to 4.61 g./100 ml. sap; the differences between varieties were not statistically significant.

Seasonal trends in the composition of the expressed sap were again observed. The concentrations of sugars and total solids increased to a maximum at the end of July, whereas titratable acidity reached a maximum early in the season during June and decreased subsequently.

The main conclusion from the work during 1959 is in agreement with that found previously; tomato varieties differ far more consistently in the acidity of the fruit than in total solids or sugar content when grown under comparable conditions.

Studies of the non-volatile acids of the tomato fruit (J. N. Davies)

In order to obtain more detailed information concerning the acidity changes observed in previous investigations of tomato fruit composition a quantitative study of the individual non-volatile acids of the tomato has been started. Anion exchange resins have been used for the separation of organic acids by several workers. Busch *et al.* (2) developed a technique for the separation and quantitative analysis of the organic acids of the tricarboxylic acid cycle in animal tissues, and this has been adapted by Palmer (11) for the study of the acids of tobacco leaf and by Hulme and Wooltorton (6) for the organic acids in pome fruits. The method depends on the fact that, when a solution containing organic acids is run on to a column of a strongly basic anion exchange resin in the acetate form, the organic acid anions combine with positively charged groups on the resin, and remain fixed thereto until displaced by gradually increasing strengths of acetic acid followed by formic acid. This technique of gradient elution chromatography on anion exchange resins is being used in a study of the non-volatile acids of the tomato fruit. Prior to adsorption on the column of anion exchange resin (Dowex-1) the sample of expressed tomato sap is treated with deactivated charcoal followed by passage through a column of the ion exchange resin Zeokarb-215 to remove cations and amino acids.

Considerable attention has been given to investigating the sequence of concentrations of eluting acids required to separate adequately the acids present in expressed tomato sap. Tentative identification of the acids present has also been made by means of paper chromatography in several solvents. The following acids have so far been identified by this means in the expressed sap:—citric and malic acids, the two acidic amino acids glutamic and aspartic (which are not held by the Zeokarb-215), phosphoric acid, and a uronic acid which appears to be galacturonic acid. Another acid, absent in the expressed sap but invariably present in alcoholic extracts of tomato fruit, is pyrrolidonecarboxylic acid. It seems probable that this acid is formed from either glutamine or glutamic acid during the preparation of the alcohol extract; it has been reported to occur in canned tomato juice (13). At least one other acid, as yet unidentified, is present in the alcohol extracts of tomato fruit.

An investigation of the quantitative changes in the individual acids of the tomato fruit during ripening has begun. Extension of these studies to various aspects of fruit composition is envisaged, especially with regard to fruit quality.

Pectic enzymes in tomato fruit (G. E. Hobson)

Studies on the pectic enzymes, commenced in 1958, have been continued with particular reference to pectin methylesterase activity and the estimation of pectic substances in tomato fruit.

The method used for estimating total and soluble pectic substances in 1958 (5), based on titration of the free carboxyl groups of the pectin chain followed by hydrolysis and estimation of esterified carboxyl groups, proved somewhat unsatisfactory for tomato fruit, and alternative methods were therefore examined. The procedure finally adopted in 1959 was the colorimetric method of McCready & McComb (8) used in conjunction with a method of extracting the pectic substances based on that of Potter (12); the method involves the enzymatic hydrolysis of pectin to galacturonic acid, followed by estimation of the latter compound. Application of this method to tomato fruit graded by colour into five stages of ripeness shows that the total content of pectic substances decreases somewhat during ripening, accompanied by a very marked increase in the proportion of the pectic material which is soluble.

The method used for estimating pectin methylesterase activity (7) has proved highly satisfactory. A linear relation between enzyme activity and concentration has been established, as also has the absence of any appreciable amounts of enzyme-inhibiting substances in the tomato. The efficiency of the extraction of pectin methylesterase from tomato fruit has been examined; in the procedure adopted the tissue is extracted three times, the proportions of the total enzyme activity found being 91.1%, 7.3% and 1.6% respectively for successive extractions. The stability of pectin methylesterase during storage at —16° C. has also been studied, as it is rarely possible to make all determinations on the fresh fruit without delay. The activity of the enzyme appears to decrease very slowly on storage at this temperature, the rate being of the order of 1—2% per month. When expressed as enzyme activity per unit of protein nitrogen the results appear to be relatively constant within the limits of experimental error. It thus seems that tomato tissue for studies on pectin methylesterase activity can conveniently be stored at low temperatures without appreciable change.

Studies on both pectic enzyme activity and the content of pectic substances in normal, "blotchy" and "waxy" fruit have shown interesting results. Thus whereas little difference was found between the total content of pectic substances in paired samples of normal and "blotchy" tomato fruit, the proportion of these pectic constituents present in soluble form was considerably higher in normally ripened tissue as compared with "blotchy" or "waxy" tissue. As shown in Table VII, the "blotchy" areas of the fruit possess a lower pectin methylesterase activity; data for the one set of fruit showing "greenback" so far examined also suggest a relation between this form of defective ripening and enzyme activity.

TABLE VII

PECTIN METHYLESTERASE ACTIVITY IN NORMAL AND IN TWO TYPES OF ABNORMALLY RIPENED FRUIT OF TWO VARIETIES OF TOMATO

Variety	Type of fruit	Pectin methylesterase activity*	
		Per 100g fresh tissue	Per 100g dry matter
'Potentate'	Normal	5.1	106
	"Blotchy"	2.7	54
	"Waxy"	2.3	49
'Immuna'	Normal	7.0	137
	"Blotchy"	3.2	62
	"Waxy"	2.5	47

*The unit of activity is here defined as the quantity of enzyme which would liberate 32 mg of methyl alcohol from pectin in 1 minute at 27°C. in 0.05M-sodium acetate at *p*H 7.5

There is much evidence to suggest that the degree of esterification of pectic substances markedly influences the physical properties of cell walls. Recently it has been found that plant growth substances strongly affect the desorption of pectin methylesterase from plant material, thus providing a possible mechanism by which physical changes in the cell wall are controlled. Preliminary experiments here have shown that plant growth substances appear to affect both the ripening behaviour of whole tomato fruit and the desorption of pectin methylesterase from fruit wall material, but much further work would be necessary before the underlying mechanisms could be established.

The effects of certain enzyme inhibitors on the ripening of tomato fruit have been the subject of preliminary trials. Injections of 2:4-dinitrophenol into mature green tomatoes at concentrations of 1—2.5 $\times$ 10^{-5} moles per fruit increased the rate of ripening of fruit left attached to the plant, but the ripening of detached fruit was unaffected.

Mushroom research (P. B. Flegg)

The year has been mainly occupied in completing experimental work already in progress, and in introducing new techniques for further studies on fruiting, including the development and construction of constant environment chambers as foreseen in the Report for 1958.

A paper on the relation between moisture stress and fruiting, based on the effects of soluble salts added to the casing layer and compost, was presented at the Fourth International Congress on Mushroom Science at Copenhagen in July, 1959. Apparatus for the measurement of moisture stress in soil, peat and compost is now being assembled. The method employs the Peltier effect to cool the tip of a thermocouple suspended in an atmosphere of high humidity; water condenses on this couple, which can then be used as a highly sensitive instrument for the measurement of equilibrium humidity, analogous to the familiar "wet and dry bulb hygrometer".

Several points of practical interest have arisen from studies on moisture stress and fruiting, and three articles on this subject have been prepared for publication in the Bulletin of the Mushroom Growers' Association. From the combined data of ten experiments it is now clear that the increased size of individual mushrooms achieved by the addition of soluble salts to the casing layer is inevitably accompanied by some loss in yield. The addition of salts to the casing layer cannot therefore be recommended as a routine procedure, but may still be beneficial where crops tend to consist of large numbers of small, fragile mushrooms. It has also been shown that the natural accumulation of soluble salts in the casing layer is not dependent on the presence of mushroom mycelium, and is insufficient to cause a decrease in crop yields of any practical importance.

Studies of the fruiting of the cultivated mushroom would be incomplete without an investigation of the factors affecting the formation and development of the thickened strands (rhizomorphs) from which the sporophores originate. For this purpose mycelium is being grown in compost placed in transparent containers made from two parallel sheets of "Perspex" (9 x 6 in.) mounted $\frac{1}{2}$ in. apart, particular attention being paid to the moisture content and density of packing of the compost. Growth and development of the mycelium and thickened strands is observed and recorded at regular intervals, and photographs have been obtained showing the connection between the rhizomorphs and the developing sporophores.

Equipment for the study of mushroom growth under controlled conditions has now been constructed, following preliminary developmental work in 1958. Eight identical chambers have been provided, each 1 ft. high internally and having an area of 5.64 sq. ft.; in these chambers the temperature, humidity and air-flow can be controlled independently. The equipment is now undergoing operational trials, which are being undertaken in co-operation with Miss Gandy of the Mycology Department. An account of the design, construction and performance of the equipment will be published in due course.

It is a common experience of most workers engaged in cropping experiments with mushrooms that the variability between plots receiving apparently identical treatments is high. In order to find the causes of this variability various cultural practices are being investigated in co-operation with Mr. D. Cooke (Statistician). No significant differences were found between two groups of pickers (men and women), nor did the usual practice of not picking on Sunday significantly

affect yields. Of practical interest was the finding that yields from beds which were "trashed" regularly did not differ significantly from those where this operation was omitted; if this result can be confirmed then a considerable saving of time and labour would be possible. One factor which was found to vary considerably was the quality of the compost along the length of the stack. In future trials it will be necessary to confound variations from this source with block differences in the statistical layout.

Three trials were sponsored at the Stockbridge House Experimental Horticulture Station, Cawood, Yorkshire, two of these arising from work done previously at this Institute. This work had shown increases in yield of up to 25% from the addition of 2 — 6 oz. per sq. ft. of milled, dried compost to the casing layer. The preparation of milled compost, however, would present considerable problems on a commercial scale, and the trials at Cawood were therefore made with moist, chopped compost. Yields were somewhat reduced by adding $\frac{1}{2}$ to $2\frac{1}{2}$ lb. per sq. ft. of moist compost to the casing layer, and further work will be necessary to reconcile these two sets of results. Arising from studies at the Institute of the effect of adding soluble salts to the casing layer on the size and yield of mushrooms, trials with a rather less soluble salt, gypsum, were conducted at Stockbridge House; the solubility of this material would be such as to safeguard the grower against any adverse effects of excessive applications. No significant response in either yield or numbers resulted, however, from applying $\frac{1}{4}$ to $\frac{1}{2}$ oz. gypsum per sq. ft., although it may be noted that some growers already incorporate gypsum in their casing material.

In recent years the production of hard, stiff wheat straw, typified by the variety 'Capelle Desprez', has, in some instances, led to difficulties in composting. In order to examine this problem, straw from two varieties of wheat ('Capelle Desprez' and 'Svenno') and from one variety of barley were treated according to the M.R.A. synthetic composting procedure for periods of three and four weeks. The barley straw gave rather similar yields, whether composted for three or four weeks, but yields from the wheat straw were higher after the longer period of composting. The most puzzling feature of the results, however, was that the 'Svenno' wheat straw, not normally considered to be of a type difficult to compost, showed a greater response to the extended period of composting than did the "hard" straw of the variety 'Capelle Desprez'. These results were unexpected, but in practice it seems that growers are learning to deal satisfactorily with the newer types of straw, and the problem may well prove to be less serious than was once thought.

The collaboration of the Director and staff at Stockbridge House E.H.S. in the conduct of the mushroom experiments carried out there is gratefully acknowledged.

Propagation in sand/peat and sand/peat/clay composts (P. J. Sutton and G. W. Winsor).

While holding a Ministry of Agriculture post-graduate scholarship in horticulture, Mr. P. J. Sutton was attached to the Chemistry Department and undertook an investigation of composts prepared from ingredients other than loam.

After studying published work in this field, in the course of which a review of the literature was prepared (15), experiments on the propagation of tomatoes and antirrhinums were commenced in November, 1958.

Five series of trials were conducted within the time available, the last two of which were on a relatively large scale. The composts examined included up to five different sand/peat mixtures, based on work done at the University of California (1), together with a soil/peat/clay mixture as described by Dempster (4); in order to provide comparison with more conventional propagating mixtures, composts prepared according to the John Innes formulas were also included.

Published recommendations for incorporating fertilizers and liming materials in the U.C. mixtures vary somewhat according to the proportions of sand and peat, but no systematic basis for such differences is readily apparent. With one exception, therefore, the fertilizer dressings in any one experiment were the same for all proportions of peat and sand, and different levels of application of lime (carbonate) were studied in factorial combination with the U.C.-type composts. A full account of the work is presented in a separate article elsewhere in this report.

Studies on the germination of antirrhinums and tomatoes in sand/peat mixtures suggest that composts of this type are at least as good as the J.I. seed compost, and in some cases (for tomatoes) superior. There was a consistent trend towards a higher percentage germination of antirrhinums at the higher levels of lime.

Comparison of U.C. composts B, C and D (sand: peat ratio 3:1, 1:1 and 1:3 by volume) with J.I.P.1 and Dempster's sand/peat/clay compost, all prepared strictly according to published specifications, showed that under the conditions of this particular trial (dull weather, supplementary mercury-vapour lighting) U.C-compost "C" was as good as J.I.P.1 when compared on the basis of fresh weight per plant in "60"-pots. Under these conditions a high content of peat (75%) was clearly undesirable, and plants grown therein were chlorotic.

The last two series of trials, in which the growth of tomato plants in "60"-pots was studied in different combinations of sand/peat mixtures and liming levels, were conducted under much brighter weather conditions in April and May. Under these circumstances it is not surprising that, in contrast to the previous experiment under dull, damp conditions, the most satisfactory sand/peat composts were those containing a high proportion of peat; none of the sand/peat composts (25—75% peat by volume) was as good as J.I.P.2 under these conditions. The inclusion of clay of the type used by Dempster had an adverse effect on growth as compared with composts containing only sand and peat.

Despite the use of relatively large numbers of plants in these trials (over 1,000 pots in the later series), much further work remains to be done on the subject of sand/peat mixtures for pot work. The results to date even suggest that the optimum proportion of peat may vary according to weather conditions, being highest in bright, dry weather. Furthermore, the nutritional aspects of sand/peat composts present several problems; thus phosphate deficiency symptoms were widespread in plants grown under high light conditions, but absent in a trial conducted in dull weather earlier in the year. Chlorosis of the leaves of young tomato plants also occurred when grown in composts having a high proportion of peat, particularly in trials conducted in dull weather (February). In keeping with the University of California recommendations the ingredients of the composts were steam-sterilized, and hence this chlorosis may well have been due to manganese toxicity from the sterilized peat; the chlorosis was certainly more marked at low levels of liming, as would be the case with manganese toxicity, but no analytical work has yet been undertaken.

Among the many lines of development which may be suggested for further study of sand/peat composts, the availability and retention of plant nutrients certainly requires attention. Whether or not steam-sterilization of fresh sand/peat mixtures is necessary or even desirable should also be established under the conditions prevailing in this country.

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4. STATISTICS

by

D. COOKE

Design and analysis of experiments

A high proportion of the work carried out during the year has been in the form of assistance to other research workers in the design and analysis of experiments. Two difficulties which arise in this work, which relates to a large number of experiments outside as well as inside the Institute, are worthy of special mention. One arises in the design of experiments to investigate different environmental treatments (e.g., different temperature regimes). The normal commercial houses, which are used for much research work, are much too big for this type of experiment where the treatments must be applied to a complete unit, usually a whole house. It is impossible to obtain adequate replication of these treatments without demanding a ludicrously large area of glasshouse space. Frequently it is necessary to resort entirely to replication in time which, obviously, greatly increases the time before any useful results are obtained and, moreover, often introduces complications in interpretation because of the large variations in weather, and perhaps handling, from season to season. For this type of experiment, what is required is a large number of small glasshouse units. Probably small houses will normally be best, but a partitioned house might be adequate for many purposes. This should be borne in mind when planning any area of glass for research.

The second springs from the large amount of time that must be spent to fully record the yield of a tomato crop. The large number of harvests of the fruits and the complexity of their grading make the task an immense one. In some experiments, plots cannot be made as small as the size which would make most efficient use of the space available because of the consequent increase in the labour of recording; alternatively, the plots can be made small, but a simplified scheme of grading has to be used. This is an important problem in experimental design in glasshouses, and it is intended to investigate possible sampling methods to cut down the labour required.

Use has been made of the facilities offered by the Statistics Department of Rothamsted Experimental Station for work to be carried out on the electronic computer there. It is intended to make increasing use of this computer for routine analysis of data from experiments carried out at the Institute and those from experiments, designed by the Statistician, which are carried out at the N.A.A.S. Experimental Horticulture Stations.

Experimental techniques with mushrooms

The percentage standard error, per tray, of mushroom yields obtained in the houses at the Institute is very high. Two experiments have been carried out, in co-operation with Mr. Flegg of the Chemistry Department, in the hope of finding the sources of this large variability.

In the first experiment the trays were treated uniformly, to investigate the effect on yield of position in the house. The only positional effect observed was that between the east and west halves of the house; but the halves were filled on different days and different parts of the compost heap were used, so the effect was not necessarily directly related to position. No difference was found between the yield on different shelves, though this is a common experience. The large effect found was that between the yield of trays containing compost from different parts of the compost heap. Inclusion of the variance due to these differences in the error variance increased it by 40%.

It is therefore advisable to fill all trays which are going into the same block with compost from the same part of the heap. A current experiment is testing if the variability is decreased by mixing the compost, for each block, very well before filling the trays. Also, in the first experiment, the weight of compost put into each of a sample of trays was determined when the trays were filled. These weights were found not to be correlated with the yields of the trays.

The second experiment investigated two further factors which might influence variability. These were the picker, since it is rarely possible for one person to pick a particular set of trays throughout the cropping period, and the effect of not picking a tray on a particular day, which may happen on some weekends and occurs when some trays are in full flush and others not cropping, but differences resulting from these factors were not detected.

Timing of harvests in horticultural experiments

A simple mathematical model of the way in which the yield of a crop changes with time has been used to investigate the choice of times of harvest in horticultural experiments. The aim has been to minimize the bias in the difference of treatment means resulting from treatments not being harvested at comparable times. This is likely to be a problem with any crop in which the part to be harvested is growing rapidly over the harvest period. A particular example is lettuce; by using an estimate of the growth rate of lettuce over the period at which it is normally harvested certain suggestions on how to harvest lettuce in experiments may be made and are given here.

To harvest a plot in a single cut does not appear to be a good way; to take the whole experiment in a single cut appears worse. A much better method is to inspect the experiment at regular intervals and remove from every plot produce which is marketable. Provided that inspections are made regularly the interval between inspections may be quite large. The determining factor will normally be the length of time a lettuce may be left before it passes beyond the marketable stage. Cutting will normally begin as soon as some lettuce in the experiment are ready for cutting. On any plot this proportion may reach 25% without harm provided none of the lettuce has passed beyond the marketable stage. It is important to ensure that this proportion is not exceeded on plots of early maturing treatments. Cutting should continue until the proportion of uncut lettuce on every plot is less than 1%, excluding plants which are not capable of maturing. If harvesting finishes before this time it may be necessary to adjust the total yields.

For certain types of crops the experimenter may decide that he particularly wishes to investigate the yield obtained when the crop is taken at one cut, or, as with peas, it may be impracticable to pick the crop over regularly. In this case it is best to get some idea of the influence of the time of harvest on yield by splitting plots into a number of sub-plots which are harvested at different times. For example, three sub-plots might be used with the intention of harvesting one at what is reckoned to be the best harvest time, with the other two sub-plots taken a few days before and after. The time of harvest then becomes an experimental treatment and the experimenter has a measure of its effect.

The growth rate of mushrooms

In order to pursue studies on the influence of time of harvesting on the yield of a crop, the growth rate of a crop of mushrooms was determined. The method chosen was to select a number of groups of mushrooms at the large pinhead stage. One mushroom from each group was harvested at random on eight successive days and the weight and dimensions of the chosen mushrooms measured. From these records it was possible to determine the growth rate of the crop.

Over the eight days of recording, the weight of the mushrooms, when plotted against time, followed a sigmoid curve. On the average the mushrooms reached the button stage on the second day after recording commenced, the cup stage on the third day, and the flat stage on the fourth and later days. From the second to the fifth day, which included the stages at which mushrooms are normally harvested, the growth was approximately linear and equalled 8.66 g per day. Since the average weight on the second day was 8.91 g, it will be seen that the average weight of the mushrooms doubled from the second to the third days, increased by a half from the third to the fourth day, and by a third from the fourth to the fifth day.

Work for outside bodies

The Statistician continued to serve on the Bulbs, Flowers and Glasshouse Working Parties of the Agricultural Improvement Council's Experimental Horticulture Committee. A major project arising out of this work was the conduct, with Mr. G. F. Sheard, of a sample survey of tomato varieties grown in Great Britain. An account of this survey is given elsewhere in this report (page 126). A total of 36 experiments has been analysed for outside bodies involving 1,584 plots and an average of 4.2 variates per plot; 35 of the experiments have been carried out on Experimental Horticulture Stations, and the remaining one came from another N.A.A.S. source.

An interesting application of the theory of the design of experiments came from the request for a method of arranging visits of certain officers to a number of institutes so that each officer would visit a different institute each year but that over the years taken to visit all the institutes the officer would meet the majority of the other officers. By putting the officers into small groups and arranging these groups in a Graeco-Latin square, it is possible to fulfil these conditions.

5. ENTOMOLOGY

by

N. W. HUSSEY

Future studies on acaricidal resistance in Red Spider Mite and work on the effect of environment on population balance between Glasshouse White-fly and its parasite both require special facilities for maintaining populations of these small arthropods free from contamination. These are being planned, but until they are available work on these pests is restricted, and the Department has therefore undertaken studies on leaf-mining flies in the family Agromyzidae.

Glasshouse White-fly (*Trialeurodes vaporariorum* Westw.) (N. W. Hussey & Barbara Gurney)

Some factors affecting white-fly fecundity through variations in the metabolism of the host plant were investigated (see special article on page 99).

Glasshouse Red Spider Mite (*Tetranychus urticae* Koch) (N. W. Hussey & W. J. Parr)

Further studies on the effect of water films on spider mites were made by altering the structure of the superficial wax layer of the leaves. Juniper (1959) has demonstrated that this may be achieved by pregermination treatment of the seed with trichloroacetic acid. These tests suggested that as the water film on the leaf, under saturated conditions, became more continuous, oviposition declined. On artificial surfaces mite mobility decreased as the thickness of the film increased.

In the future, work on the mechanisms governing the development of acaricidal resistance in populations of *T. urticae* is proposed. Before undertaking these studies it will be necessary to understand the complex of species and strains included in the taxonomic definition of *T. urticae*. At present, the status of the American species *T. bimaculatus* Harvey and *T. cinnabarinus* Bois, and the European species *T. urticae* is disputed, and the cross-breeding studies made by earlier workers have given inconclusive results.

Studies have been made on the specific status of the British and American colour forms by cross-breeding experiments, using more pairs and recording the fertility of the females and viability of the eggs in greater detail than in earlier studies. It was shown that the red forms were entirely incompatible and must be considered specifically distinct. The green forms, however, readily interbred, but the fecundity of the parent females was abnormally low. Although fertility was normal in the F_1 generation the eggs were largely non-viable. It is doubtful, however, whether these inconsistencies constitute more than differences between geographical strains of the same species.

Mushroom Phorids (N. W. Hussey)

Tests on contact and vapour repellents against the adults were concluded and dimethyl phthalate was shown to be the most promising material.

Research on different techniques for rearing these flies in artificial culture continued, but a suitable method of obtaining viable eggs has not yet been perfected. All stages can be reared readily once the eggs can be extracted from spawned compost by agitation, in water, over a gauze liner in a Baermann funnel. Small blocks of spawned compost readily attract ovipositing flies in a cropping house, but in cages the eggs laid are infertile. The difficulty probably involves the optimum flight requirement for the successful fertilisation of the female. Tests on methods for reducing the scale of natural infestations have therefore been made by exposing treated jars of

freshly spawned compost in the cropping house during the flight period of vast numbers of *Megaselia halterata*. Surface application of 1% BHC dust and daily spraying with dimethyl phthalate were ineffective, but a synergised pyrethrum dust considerably reduced oviposition. Analysis of the compost from beds, following a mass flight of adults, showed that oviposition was markedly decreased where BHC and Aldrin had been incorporated in the casing layer at 100 and 50 p.p.m. respectively.

Studies on the morphology of the larvae of the two species *M. halterata* and *M. nigra* are in progress with special reference to the differences in structure of the mouth-parts associated with different feeding habits.

Investigations on the life-cycle of the parasitic eelworm *Bradynema* were continued.

Mushroom Cecids (I. J. Wyatt and N. W. Hussey)

An experiment with agar cultures to test whether the weed fungus *Chaetomium* had a beneficial effect upon the reproduction of Cecid larvae showed that *Heteropeza pygmaea*, *Mycophila speyeri* and *M. barnesi* all bred more successfully on this fungus than on mushroom. Transference tests between these fungus hosts suggested that even a short feeding period of *Chaetomium* improved subsequent reproduction on mushroom. This observation may have important implications in commercial practice if the presence of this weed fungus in the compost increases the reproduction rate of Cecids so that large populations result before cropping begins.

More intensive studies were made on the effect of temperature on the development of all the four recognised species of mushroom Cecids. It is concluded that temperature is a major factor limiting population growth, and further work may reveal a practical method of restricting outbreaks.

Earlier work had shown that BHC in the casing slowed population increase in the compost, and a laboratory experiment was done to find out if this was caused by fumigant action. The technique adopted was to insert filter-papers, soaked with different strengths of insecticide, into the mouth of test tubes containing mycelial cultures on agar. The results suggested that if BHC controlled Cecid larvae by fumigation, it would do so only at concentrations which inhibited mycelial growth. On the other hand, low concentrations of the order of .01% BHC actually appeared to stimulate reproduction.

The principal damage caused by Cecid larvae is the spoiling of marketable crops by migration on to the sporophores. Several experiments were made to investigate some of the factors governing larval movement. Under moist conditions the larvae are negatively geotropic and positively phototropic, which explains the frequent appearance of larvae on the bed surface after watering. Normally, however, the larvae remain within the compost, and this must be accounted for by (1) the strong attraction to growing mycelium, (2) the migratory tropisms being initiated only in response to starvation or overcrowding, or (3) the fact that as the larvae tend to move upwards they normally encounter the drier casing layer, which reverses the tropisms.

Observations were made on the factors influencing the efficiency of our methods for extracting larvae from compost, and it was concluded that a method using moving water down a column of compost would be the most satisfactory.

In the cropping house a comparative trial was made to measure losses due to the three common Cecid species. Damage by *Mycophila* exceeded 50%, *M. barnesi* affecting the mushrooms between the 4th and 7th weeks of cropping and *M. speyeri* climbing on the sporophores during the first four weeks. *Heteropeza* affected 21% of the crop between the 5th and 7th weeks. By treating the casing of beds, inoculated with *Mycophila speyeri*, with 100 p.p.m. BHC the losses were reduced from 66% in the control plots to only 1%. Malathion mixed with the casing, and weekly spraying with synergised pyrethrins, were less effective.

In another crop BHC and Aldrin mixed with the casing at application prevented losses due to migration of *Mycophila speyeri* on to the sporophores, even at the lowest concentrations (10 p.p.m.). Aldrin did not affect the size of the mushrooms, unlike BHC, but when compared with controls cased with untreated peat neither chemical reduced yields.

A study was made of spread from a central inoculation of beds with *Heteropeza* larvae, and it was shown that population increase was exactly logarithmic. The final populations measured suggested that an average of 7.4 young larvae must have been produced every 12.6 days.

Earlier experiments had suggested that the incorporation of malathion and dimetan in the compost tended to increase yields, but more extended trials using these materials at 10 p.p.m. failed to confirm the effect. At 10 p.p.m. gamma BHC, malathion and dimetan did not reduce Cecid populations.

Descriptions of both sexes of the new species *Henria psalliotae* Wyatt were prepared for publication.

Agromyzid Leaf-miners (W. J. Parr, N. W. Hussey and Barbara Gurney)

A study of the factors influencing choice of oviposition site by leaf-miners was begun, with special emphasis on the polyphagous species *Phytomyza atricornis* Mg.

To facilitate continuous experimentation it was necessary to determine the factors which induce pupal diapause in this species during the winter months.

A reduced daylength of 8 hours acting on the adult flies during oviposition, or on the larvae during development, failed to produce diapause in the pupal instar; nor was any effect obtained by keeping developing larvae at mean temperatures of 48° and 60° F.

The chilling of pupae at 47° F. for different periods of time during this instar delayed emergence only to a small extent, though there was a considerable decrease in the number of emergent flies when the period of chilling exceeded two days. On the other hand, flies from pupae kept continually at 40° F. did not emerge until 55 days after the formation of the puparia.

These observations suggest that this species does not in fact enter true diapause providing sufficient food is available, but that a continual period of excessively low temperature may prolong the pupal period considerably.

The rate of development of each stadium has been worked out in the laboratory at a temperature of between 65°—75° F. The life-cycle from the laying of the egg to the emergence of the adult occupied about three weeks.

When kept at 47° F. adult flies remained alive for at least three weeks. On removal to a higher temperature the mated females laid viable eggs, and the rate of development of the progeny did not differ appreciably from that of progeny reared from flies kept at a mean temperature of 65° F.

In addition to the laboratory observations, a survey of species associated with ornamental plants is being made.

The parasites of *P. atricornis* on different host plants show several interesting associations which are being studied.

Soil Fauna (W. J. Parr and Barbara Gurney)

Extraction of soil fauna from plots which have been sterilized by different methods continued.

REFERENCE

JUNIPER, B. E. (1959). The surface of plants. *Endeavour* **XVIII**, 20-25.

6. MYCOLOGY

by

P. H. WILLIAMS

The work of the Department has followed in the main the same lines as in the previous year. Experiments have been done on the spread of *Didymella* Stem Rot of tomato, on Cucumber Mildew, carnation wilts and "Watery Stipe" and yellow moulds of mushroom. In collaboration with the Virology Department an investigation has been started on a disease of polyanthus. Further work on Petal Blight of chysanthemums has been hampered by the dry summer which was unfavourable to the development of the disease. Dr. Stone has assisted in the work on the production of virus-free carnations, and an account of her experiments will be found in the report of the Virology Department.

Didymella Stem Rot of the tomato (P. H. Williams)

Spread of the disease by watering

Tomato plants, variety 'Potentate', were grown in shallow trenches delimited by sheets of asbestos. Three treatments were applied. In one, the end plant of the row was inoculated with *Didymella lycopersici* just above soil level and the plants were watered by means of a hose. In the second, plants similarly inoculated were watered by trickle irrigation, and the third was an uninoculated control also watered by trickle. The treatments were arranged in randomized blocks. Although all the inoculated plants developed lesions with spores, none of the other plants became infected, suggesting that watering is not an important factor in the spread of the disease.

Susceptibility of wounds to infection

Tomatoes, variety 'Potentate', were grown in 9 in. pots. When they were large enough every third leaf was cut off. Wounds on one set of plants were inoculated immediately with spores of *D. lycopersici* and on other sets after three days, one week, two weeks and four weeks. There were seven plants in each set, and the position of plants inoculated at any one time was randomized in the rows. When examined finally, 46 days after inoculation, the following were infected out of 7 plants and 42 wounds:—

Inoculated	immediately	3	plants	3	wounds
,,	after 3 days	3	,,	5	,,
,,	,, 1 week	0	,,	0	,,
,,	,, 2 weeks	1	,,	1	,,
,,	,, 4 weeks	1	,,	1	,,

The experiment was repeated with modifications. The leaves were broken instead of being cut off. All the plants were inoculated at the same time, removal of the leaves being timed to have the same intervals between wounding and inoculation as before. The final infection figures 62 days after inoculation were:

Inoculated	immediately	7	plants	12	wounds
,,	after 3 days	2	,,	4	,,
,,	,, 1 week	0	,,	0	,,
,,	,, 2 weeks	0	,,	0	,,
,,	,, 4 weeks	2	,,	3	,,

In both experiments the number of plants infected was greatest in plants inoculated immediately or three days after wounding. The larger number of plants and wounds infected in the second experiment may have been due to the lower temperatures and higher humidities prevailing during the experiment. Most lesions developed at the 6th, 9th and 12th nodes, where the remaining foliage was densest.

Soil extracts and spore germination

In previous work it was found that while spores of *D. lycopersici* did not germinate in the presence of unsterilized soil, soil solution extracted by different methods was not toxic to them. Further experiments with water and alcoholic extracts have been done this year.

Water extracts were obtained by shaking unsterilized soil with water, filtering through filter paper and sterilizing the extract by passing through a L7 candle or a Ford Sterimat of sterilizing grade. Alcoholic extracts were made in two ways. In one the soil was extracted in a Soxhlet apparatus, an equal quantity of water being added to the extract and the alcohol evaporated off. In other experiments, soil was shaken in alcohol, filtered, and the alcohol evaporated off either by bubbling air through it or by heating over a waterbath at 30° C. Both residues were taken up in a small quantity of water.

While in some experiments there was evidence of toxicity to spores in the extracts, irregularity of germination of spores made interpretation difficult. Attempts were made to overcome this by testing germination of successive lots of spores from the same culture or of spores from cultures of different ages, but it proved impossible to standardise the spore suspension and hence to get reliable results in tests of soil extracts.

Cucumber Mildew (Olwen M. Stone)

Experiments were continued on the host range of Cucumber Mildew.

Plants of *Sonchus asper* infected with mildew from cucumber were overwintered in a cold frame. When tested in the spring, the mildew on these plants was capable of infecting cucumbers.

Specimens of *Plantago lanceolata* and *P. major* bearing conidia and perithecia of *Erysiphe cichoracearum* were potted up during the summer. Attempts to infect cucumber seedlings in tubes with spores from these plants were unsuccessful. Further cross-inoculation experiments are in progress.

Chrysanthemum Petal Blight (*Itersonilia perplexans*) (Olwen M. Stone)

A number of plant species which might be susceptible to this disease were planted in a bed near the packing shed in the spring. Despite frequent inspections, no *Itersonilia* was found during the whole season.

Cuttings of chysanthemum, variety 'Yellow Ace', taken from heavily infected plants in the winter of 1958/59, were grown and flowered in a glasshouse. No infection occurred. The old infected stools were kept in the open and grew up again and flowered, but remained healthy. The chrysanthemum crop at the Institute also remained healthy.

It appears that, under the very dry conditions of the summer, the fungus was unable to cause infection.

Carnation Wilt Diseases (Marion H. Ebben)

Wilt in steamed and unsteamed soil

Six plots at the north end of house E1 were used in this experiment. Three were steamed in October, 1958, and, after base dressings had been applied, all were planted in November with three varieties, 'William Sim', 'Ashington Pink' and 'Northland'. Analyses showed that the *p*H and *p*C of the steamed and unsteamed soils were similar.

Soil samples for analysis of the fungi present were collected during March, 1959. The numbers of fungi were 268,000 and 543,000 per gm. of dry soil in the steamed and unsteamed soils respectively. Samples of the mineral sediment and floating organic debris were collected from the dilution flasks and used to determine the species present. Species of *Penicillium*, *Mucor* and *Trichoderma* were found in both fractions of both soils, and *Chaetomium* spp. in all except the organic fraction of the steamed soil. *Myrothecium roridum* occurred in both fractions of unsteamed soil, while *Aspergillus* sp. and *Fusarium oxysporum* were found only in the mineral fraction of unsteamed soil. During the next twelve months 20 plants became diseased in the unsteamed plots in contrast to six in the steamed. In the unsteamed plots, 'William Sim' was most severely affected (11 out of 90), all being attacked by *Fusarium roseum*. In 'Ashington Pink' five plants were attacked, three by *F. roseum* and two by an *Alternaria* sp. resembling *A. dianthi*. In 'Northland' four plants wilted, and from all *Alternaria* sp. was isolated. In the steamed plots, 'Northland' was the worst affected, *Fusarium* and *Alternaria* being implicated.

Experiments on the pathogenicity of the *Alternaria* are in progress.

Varietal susceptibility to Pectobacterium parthenii var. dianthicola

Five strains of the Slow Wilt bacterium were used to inoculate the six carnation varieties 'Pink Betty Lou', 'Harvest Moon', 'Apollo', 'Cardinal Sim', 'Clayton Crimson' and 'Petersen's Sim'. Infected match sticks were pushed into the soil under the plants, and broth cultures were watered on the soil at the beginning of June. Development of symptoms was recorded and re-isolation of the pathogens attempted. At the end of October all plants from which the pathogen had not been isolated were tested by culturing shoots from near the base of the plant. At the end of the year all the surviving plants were examined for internal browning, and slices from the stem base were incubated in broth in an attempt to isolate the pathogens.

'Pink Betty Lou', 'Cardinal Sim' and 'Petersen's Sim' were most susceptible, and 'Apollo' and 'Clayton Crimson' most resistant. The strains of the bacterium differed in virulence; with two of them symptoms developed very slowly.

A polyanthus disease (Marion H. Ebben)

In recent years polyanthus plants have been attacked by a disease which causes stunting, yellowing of the leaves and eventual death. The roots also turn brown and die, but this may be a secondary effect. Several fungi and bacteria have been isolated from them, including *Fusarium oxysporum*, *Ramularia* sp., *Fusarium* sp., *Pythium* sp., *Phyllosticta* sp., and *Pseudomonas* sp.

These six organisms were tested for pathogenicity on *Primula elatior* and *P. obconica*, either by placing a culture beneath the roots or by inserting a piece of culture into a cut through the soil and roots close to the root stock, six plants of each species being inoculated with each. After three months none of the inoculated plants looked different from the controls, so the roots of all plants were examined. Those of *P. obconica* were all healthy. There was slight root damage in some *P. elatior*, but it was impossible to re-isolate any of the fungi originally inoculated.

Isolations from roots of diseased polyanthus plants during the summer yielded *Thielaviopsis basicola*. Young plants of *P. elatior* were inoculated with this fungus during October. Results to date show that some root infection has occurred, but leaf growth is normal.

When young seedlings were pricked out into pots which had contained diseased plants, half of them showed normal top growth but new adventitious roots turned brown and died back from their tips. The damage was not severe. The remainder grew poorly and some leaves turned yellow. Their roots were small with extensive lesions, especially on the younger ones; some of the older roots died back. Isolations showed that three plants were infected with *T. basicola*, one with *Fusarium* sp. and one with a pycnidial fungus.

Among second-year plants in a public park on the south coast there was a higher percentage of disease in the wetter and more shaded beds. There was also a suggestion of varietial susceptibility, more red flowered plants being affected than white or yellow when all three varieties were growing together in the same bed.

The work is being continued.

Mushroom diseases (Doreen G. Gandy)

"*Watery Stipe*"

(1) *Transmission in beds*

(a) Freshly spawned trays were inoculated with material (compost or casing) or water extracts of these materials from ten crops with suspected "Watery Stipe". Trays inoculated with material yielded only 1.5% to 87.4% (mean 27.5%) as many mushrooms as the controls; their weights were 1.2% to 78.3% (mean 20.0%) of the controls. The water extracts caused no significant difference in either number or weight of mushrooms, and mushrooms with watery stipes appeared in approximately equal numbers in both treated and control beds.

Mycelium in plots inoculated with material began to degenerate within two weeks of the first picking, and had often disappeared by the end of the experiment. Consequently it was only possible to obtain five cultures from these plots, four adpressed ones which grew poorly and one normal. From the plots receiving water extracts, 34 cultures were made of which 31 were normal, two were adpressed but grew well, and only one was adpressed and grew poorly. Of 12 cultures from control plots, 11 were normal and one was adpressed but grew well.

It was concluded from this experiment that

(i) the disorder could be transmitted by inoculation with material from affected beds but not by water extracts thereof,

(ii) the most important symptom was loss of crop, and

(iii) the disorder was associated with deterioration and disappearance of the mycelium in the compost.

Similar results were obtained in a second experiment where trays were inoculated with material from infected trays in the previous experiment.

(b) Simultaneous inoculation with spawns made from commercial spawns and cultures from abnormal crops led to almost complete failure of crop, many trays producing no mushrooms. Control trays produced normal crops. Apparently the disorder was transmitted from the abnormal to the normal spawns.

(c) To study the spread of the disorder, beds 13 ft. long were used instead of trays. They were inoculated at the centre with compost from a previous experiment, two weeks after spawning. Isolations of mycelium were made at intervals from different points in the bed. In the first flush, 34 days after inoculation, the mushrooms appeared only at the ends of the beds, none within three feet of the site of the inoculation. Thereafter no true flushes appeared, only sporadic individuals and small clumps. A large proportion of them had elongated stipes and watery streaks, and many died. The size of the bare area increased slightly. Mycelial degeneration spread from the site of inoculation and, at the end of the experiment, mycelium was found only at the edges of the beds. The disorder may spread most rapidly when the mycelium is growing quickly during spawn run, and experiments to test this hypothesis are in progress.

(2) *Pure culture experiments*

(a) It has been shown by Garrett (1954) that the rate of growth of mushroom mycelium in compost depends on the amount of inoculum. Variations in the vigour of cultures isolated from experimental plots might therefore be due to the size of the piece of mycelium plated out and not be connected with any disorder present.

Plates of malt agar of different concentrations were inoculated with pieces of mycelium of different sizes and types taken from a vigorous culture. The colonies which developed differed in size, depending on the size of the original inoculum and the richness of the medium, but all were normal in appearance. No adpressed, buff coloured colonies similar to those isolated from affected crops developed.

(b) It has been suggested that some cultures of mushrooms may be contaminated with bacteria, that such cultures produce mushrooms with watery streaks, and that they can be freed from infection by treatment with rose bengal. No bacteria were found in abnormal cultures from affected crops, and treatment with rose bengal at concentrations ranging from 1/5000 to 1/20,000 did not alter the type or rate of growth.

(c) When a normal and an abnormal culture were grown together on agar in a petri dish the mycelia were slow to come into contact, as if they were slightly antagonistic. The mycelium of the two colonies did not appear to fuse, although fusion is obvious when two normal colonies are grown together. There was no change in the appearance of that part of the normal colony which had grown before contact, but subsequent growth was often weaker, with fewer rhizomorphs. If the apparently unchanged mycelium, or the younger, weaker type was sub-cultured, growth was often weak and abnormal. All the abnormal cultures isolated from affected beds were tested, and the presence of a transmissible factor was demonstrated in each.

By cutting discs of mycelium from different parts of the colony the spread of this factor was traced across the normal colony. Several discs of mycelium from that part of the colony furthest from the abnormal one yielded normal cultures, all others being abnormal.

(d) Mycelium of normal and abnormal cultures 13 days old was macerated under sterile conditions and suspended in sterile water. Discs of agar and mycelium from a vigorous culture were dipped in the suspensions for a few seconds and put on plates of malt agar. The suspensions were then filtered to remove mycelial fragments, and more discs dipped in the filtrates and plated. Discs dipped in suspensions and filtrates of normal cultures grew normally. Discs dipped in suspensions of abnormal mycelium grew abnormally, with adpressed mycelium and few rhizomorphs. Filtrates of abnormal mycelium did not affect the subsequent growth of the discs. The infective agent was therefore not obtained free from the mycelium by the method of maceration employed, and further work on this problem is in progress.

(e) When abnormal cultures were incubated at 25° C. for six days and then at 33° C., the new growth usually became white and fluffy, with rhizomorphs, and indistinguishable from normal cultures. Sub-cultures from the margins of the heat-treated colonies continued to grow normally when incubated at 25° C. When these treated cultures were grown with normal cultures in the same plate, the rhizomorphs anastomosed in the same way as those of two normal colonies.

Cultures made from that part of the colony which had grown before transfer to 33° C. were usually adpressed and grew poorly. It appears, therefore, that heat treatment slows up the translocation of the infective agent in the mycelium so that the younger parts of the colony are wholly or partly free from it.

In further experiments it was found that growing abnormal cultures at 30° C. had a similar effect. At 35° C. the mycelium was killed, and when the dead mycelium was used in double inoculation of a petri culture with a healthy culture, there was no transmission of the abnormality, indicating that the infective agent may be inactivated at that temperature.

Experiments on the method by which the growth abnormality is transmitted are now being done.

Yellow moulds in mushroom compost

In continued work on these fungi one has been obtained in pure culture, but it does not grow well on agar media. It has therefore been maintained by growing it in bottles of mushroom spawn. Experiments are now being done to determine the conditions which favour its growth in compost. The presence of mushroom mycelium appears essential, as it has not yet been cultured on sterile compost.

REFERENCE

GARRETT, S. D. (1954). Function of the mycelial strands in substrate colonization by the cultivated mushroom, *Psalliota hortensis*. *Trans. Brit. mycol. Soc.*, **37,** 51-57.

7. VIROLOGY

by

M. HOLLINGS

Attention is being concentrated on three major problems: the epidemiology of tomato mosaic, the virus complex in chrysanthemums, and attempts to produce virus-free clones of both carnations and chrysanthemums by heat treatment and tissue culture. Other work on virus diseases has been largely the completion of problems in hand when M. Hollings transferred from the Plant Pathology Laboratory, Harpenden. The development of the work of the Department is at present limited by the facilities available, and cannot be expanded until the projected research glasshouse is built.

Carnation

Indexing of carnation varieties (Olwen M. Stone and M. Hollings)

Four viruses have been described in English carnation stocks (Kassanis, 1955) and two others (lucerne mosaic, and a virus of tobacco ringspot type) were isolated at Harpenden. Our tests could detect all but one of these viruses. Carnation mottle and carnation ringspot viruses were identified by their reactions in *Chenopodium amaranticolor* and *Gomphrena globosa*, and by serological tests using gel diffusion and precipitin tube methods. Carnation vein mottle virus could be detected by aphid inoculations to sweet-william seedlings, and lucerne mosaic and the tobacco ringspot-type virus by the systemic symptoms in *Chenopodium*, *Gomphrena* and *Tetragonia expansa*. Carnation latent virus is not known to produce visible symptoms in any plant, though when present with other viruses in carnation it can aggravate the damage caused; the only satisfactory test is a serological one, but we have not yet the facilities to prepare antisera against the latent virus. Carnation streak virus, described in the United States, has not so far been recorded in England.

Fourteen commercially important varieties of carnation, obtained from two growers, were indexed for their virus diseases as a preliminary stage in efforts to obtain virus-free plants. The varieties were: 'Ashington Pink','Cocomo Sim','Golden Rain','Harvest Moon', 'Improved William Sim', 'Joker', 'Northland', 'Peppermint Sim', 'Petersen's Sim', 'Saugus White', 'Saugus Pink', 'Sparkes' Sim', 'Tangerine Sim' and 'White Sim'.

All fourteen varieties were infected with mottle virus, and three ('Ashington Pink', 'Northland' and 'Saugus Pink') with carnation ringspot also. 'Saugus Pink' probably acquired ringspot virus during 1959.

The varieties 'Cocomo Sim', 'Harvest Moon' and 'Peppermint Sim' showed conspicuous yellowish semi-necrotic rings, flecks and streaks on the younger leaves, but no ringspot virus could be detected in them. These three varieties contained mottle virus, but grafts from 'Cocomo Sim' to 'Sparkes' Sim' (also containing mottle virus) reproduced the additional rings and flecks after 3–4 months.

Sweet-william (*Dianthus barbatus* L) has been widely used in studies on carnation viruses, but batches of seedlings usually contain plants that differ greatly in their reactions to infection with the carnation viruses, causing confusion. Some clones have proved very resistant to infection

(particularly with ringspot virus), whereas others have shown few or no symptoms (especially with mottle virus) or did not support a high concentration of virus. We are therefore testing lines of sweet-william seedlings to obtain clones that react well.

Our indexing tests support previous experience at Harpenden that carnation ringspot virus is much less prevalent than several years ago, and is usually seen in stocks of the older English varieties. Sufficient plants of the 'Sim' varieties exist free from ringspot for this virus to be satisfactorily controlled by roguing and selection. Where present, it can readily be eliminated by heat treatment or tip culture. Carnation mottle, however, is widespread; every plant of all 'Sim' varieties tested by us has been infected and, as mottle virus has not so far been eliminated by heat treatment or tip culture alone, techniques for its elimination and control provide the main problem for our future carnation work.

Carnation vein mottle virus, which is believed to be the same as the "carnation mosaic" described in the United States, appears to be uncommon in English stocks, although it occurs every year in sweet-william plants in private gardens, suggesting a natural outdoor reservoir of virus. This could endanger carnation stocks unless aphids are controlled, for the virus is readily transmitted by some aphids.

Attempts to obtain virus-free plants (Olwen M. Stone)

Two methods which have successfully eliminated some viruses from vegetatively propagated plants are heat treatment and tip culture.

(a) *Tip culture*

Between January and June 1959 about 2,000 tips, at first 1 mm. but later $\frac{1}{2}$ mm. in length, were dissected from carnation shoots and grown in small tubes containing an agar medium. This medium, used by Dutch workers, contained standard inorganic nutrients and trace elements, as well as vitamins and a growth factor. The proportion of explanted tips that survived, and their rate of growth in the tubes, differed widely; some had formed roots within three weeks (Plate I), others did so only after several months, and many failed to root at all. About seven weeks after rooting, plantlets were transferred to solid media for further growth; different media were compared for their suitability but, on the year's results, there was no significant difference between: (i) washed gravel plus nutrient solution, (ii) washed sand plus nutrient solution, (iii) vermiculite plus water, (iv) equal parts of peat and sand plus water and (v) equal parts of peat, sand and loam, plus water.

About 15% of all tips taken survived to mature flowering plants, but although a few that had previously contained ringspot virus no longer did so, all still contained mottle virus. No attempts have been made yet to eliminate vein mottle virus by tip culture.

The tips taken consisted of the meristem plus one or two pairs of leaf primordia, and the proportion that rooted was influenced by several factors. Larger tips rooted more readily than smaller ones; few tips of $\frac{1}{4}$ mm. or smaller rooted, whereas about 30% of those 1 mm. long did so. There were differences in the rooting ability of tips from different varieties, and the results of a current experiment indicate slight differences between batches of tips taken from a uniform group of plants at intervals from the rooted cutting stage until flowering.

We hope to determine how close to the meristem itself mottle virus occurs, and whether tip culture can be reinforced by other methods to obtain virus-free plants.

(b) *Heat treatment*

In preliminary experiments, rooted cuttings of 'Saugus White', about 20 cm. tall, were grown for 4 or 6 weeks at 100° F. Each plant was given 50 ml. of water daily, the minimum amount to prevent wilting. Immediately after treatment, meristem tips were cultured, and the stump of each treated plant left to grow. Carnation ringspot virus was eliminated from the rooted plants, but mottle virus remained.

In another experiment, small plants of the variety 'Saugus White' derived from previous tip cultures and 5—8 cm. tall, growing in very small plastic pots, were heat treated. The plants survived six weeks at 100° F. and though freed from ringspot virus, still contained mottle.

Meristem cuttings from these and from other batches of heat-treated plants are not yet large enough to test for virus.

Sweet-william and 'Chabaud' carnation plants, experimentally infected with carnation vein mottle virus, were heat treated for three weeks, but the thermostat control failed and a constant temperature could not be maintained. Relatively large tip cuttings (5—10 mm.) were taken from the tips of the shoots and rooted in Peralite. All subsequently developed typical symptoms of vein mottle, but valid conclusions cannot be drawn because of the temperature fluctuations during treatment.

Chrysanthemum (M. Hollings)

As with most vegetatively propagated plants, the problem with chrysanthemum viruses is to detect and recognise them, and to obtain plants free from them. There are at least ten different viruses in English chrysanthemum stocks; a plant may be infected with two or more viruses, and different chrysanthemum varieties often react in quite dissimilar ways to infection with the same virus, so that symptoms on the plant are not a reliable guide to the identity of the virus or viruses present. Standardised tests are used to identify the different viruses—for example, by grafting suspect plants to certain chrysanthemum varieties that react in a diagnostic manner to particular viruses. This method has the big disadvantage that a long "incubation period" must elapse before the result is known—from two months to two years. Efforts have therefore been concentrated on studying the properties of the different viruses so that more rapid tests, in particular serological tests, can be developed for large-scale indexing of stocks. Any virus-free plants thus found can be propagated to a working stock; but for the many varieties that seem to be wholly infected with a certain virus or viruses, therapeutic methods are being sought to obtain virus-free clones.

Heat treatment can eliminate some viruses, and culture of the meristem tissue has eliminated others, but indiscriminate heat treatment without subsequent testing could easily select a heat resistant strain of, for example, aspermy virus, which would be a severe setback.

Specific viruses under investigation

(a) *Chrysanthemum green flower.* This disease has occurred in several widely-scattered stocks of the variety 'Balcombe Perfection' and its red and amber sports; no fungal or bacterial pathogen could be found, and all the experimental evidence indicates that a virus of yellows type is the cause. Affected plants had dwarfed green flowers of no value, poor spindly growth and necrosis of the roots that later killed the plants. The disease is experimentally transmitted by grafting and, so far, only 'Balcombe' varieties have proved susceptible to infection. Though similar root damage is caused by the American "flower distortion virus", green flower virus repeatedly

failed to give the diagnostic symptoms of the American virus on variety 'Blazing Gold'. Green flower virus was transmitted from chrysanthemum to *Vinca rosea*, by dodder bridge (*Cuscuta subinclusa*) and caused apical rosetting, yellowing and chlorosis of the leaves, and greening and phyllody of the flowers. Although symptoms did not develop for 1—2 years after grafting chrysanthemum to chrysanthemum, typical symptoms showed 3—5 weeks after grafting *Vinca* to *Vinca*.

(b) *Virus D*. This is an undescribed virus that causes severe flower distortion in many chrysanthemum varieties, and whose symptoms are not always readily distinguishable from those of aspermy. The grafting test at present used to identify virus D may take 1—2 years before diagnostic symptoms develop. When chrysanthemum shoots infected with virus D plus vein mottle virus were grafted to variety 'Good News', leaf mottle, and flower dwarfing with severe floret necrosis and distortion developed six weeks later; similar grafts from chrysanthemums believed to be infected only with vein mottle virus produced only leaf mottling. If this reaction is specific for virus D, it reduces the waiting period for tests from 1—2 years to as many months. All chrysanthemum plants so far found infected with virus D have also contained other viruses. Neither virus D nor virus E (another virus that distorts flowers) could be eliminated by heat treatment of infected chrysanthemums followed by rooting small cuttings (2—3 mm. long) from the tips of the young shoots.

(c) *Chrysanthemum vein mottle*. An antiserum prepared against this virus reacted specifically with the virus in tests with infected *Nicotiana clevelandii* or petunia sap, but not so far with chrysanthemum sap. It is hoped that serological tests may indicate any relationships between the several leaf mottling viruses. Vein mottle was not eliminated from plants by heat treatment followed by rooting small tip cuttings.

(d) *Stunt*. See special report on page 104.

Tomato mosaic (L. Broadbent)

Work was started on some aspects of tobacco mosaic virus in tomato crops. Most of the experiments were done to find out more about the initial sources of virus, and included work on seeds, glasshouse structures, workers' clothing and hands.

(a) *Seeds*

Most published reports suggest that seed-transmission of TMV does not occur, but several workers have claimed to show that it does. It is now agreed that virus does not occur in the embryo, but is present in the testas of seeds from infected fruits. Over a thousand (1020) seeds from infected fruits of the variety 'Potentate', fermented for 5—7 days and then cleaned and dried, were grown individually in cartons or pots, to obviate pricking out, under conditions of isolation that decreased the possibility of virus contamination to the minimum. They were grown to the 4—5 true leaf stage and then, in addition to the frequent observations during growth, were tested by inoculating *Nicotiana glutinosa* with their sap. This plant readily produces necrotic local lesions if TMV is present in the sap. No plant became infected, although TMV was demonstrated in the testas by grinding a sample of each batch and inoculating to *N. glutinosa*.

To decrease the danger of contamination from the testa, batches of fermented, dried, infected seed were treated by soaking them in several solutions (see report by R. Howles). No treatment eliminated the virus, but as with untreated seed, none of the 700 plants grown was infected.

To find out how soon seedlings which became contaminated during their early growth showed symptoms, seeds were sown in well-separated pots watered by a trickle irrigation system. When the cotyledons expanded they were mechanically inoculated with TMV-infected tomato leaf sap diluted with distilled water at six rates from 1/100 to 1/5,000,000, using "Celite" as an abrasive. Ten plants were inoculated per treatment, leaving 15 uninoculated controls. The 75 pots were randomized on the bench. Times of appearance of symptoms were noted, and when the plants reached the 6—8 leaf stage all those not showing symptoms were tested by inoculation to *N. glutinosa*. The experiment was done four times, three with the variety 'Potentate' and different strains of TMV, once with the variety 'Moneymaker'. All gave similar results. All plants were infected when inoculated with sap at dilutions 1/100 or 1/1,000, and most were infected at dilutions of 1/10,000 and 1/100,000. Sap diluted 1/1 million infected almost half, but at 1/5 million only 3 out of 40 of the plants inoculated. No infection occurred in any of the uninoculated controls. The results showed that (i) it is possible to infect tomato seedlings with very low sap dilutions, (ii) growth of infected seedlings slowed down about a week after infection, so that 85% of them were recognised as "hard" and stunted about three days before typical mosaic symptoms began to show, and (iii) definite symptoms showed with all strains of virus 12—14 days after inoculation, with a delay of about three days only between plants inoculated at 1/100 and 1/5 million. These results suggest that if seedlings are infected as they emerge from the testa, symptoms would be readily visible when they reached the 2—3 leaf stage. Plants which show symptoms for the first time in later stages were probably infected from sources other than seed.

Although we have no evidence of seed transmission with undisturbed seedlings it is possible that seedlings are infected from the testas during pricking out, and this is being tested. Testas, infected with virus, persist in the soil for at least eight weeks after sowing. Seed stored (a) in closed bottles, (b) in open dishes at room temperatures for nine months gave 35% and 36% as many lesions, respectively, as freshly harvested and fermented seeds, when ground up with buffer solution and inoculated on *N. glutinosa*.

(b) *Structures*

Several tests were made to find out if virus persisted on glasshouse windows, wires and paintwork. Soon after the infected 1959 crops were removed, swabs were wiped over several parts of houses that had been in contact with leaves or workers' hands, but no virus was detected. Then infected leaf sap, diluted either 1/1 or 1/10, was wiped on to paint work, glass or wire, or leaves were brushed over them. Later cloth soaked in buffer solution was wiped first over the treated areas and then over *N. glutinosa* leaves. The numbers of local lesions that developed decreased rapidly with time after virus application, and few were obtained after two weeks, suggesting that virus was inactivated either by the paint or light. No lesions occurred after three weeks where sap had been applied, but a few occurred where the leaves had been brushed over, suggesting that fragments of leaf hairs or leaves had adhered to the surface.

(c) *Workers' hands*

Washing with soap and water is usually recommended for disinfecting hands after handling TMV-infected tomatoes. This was tested by handling plants for several minutes, including pinching out side shoots, and then washing with soap and water, and scrubbing the nails with a brush. Other methods tried were washing in 2% Lysol solution or citric acid solution. Healthy tomato plants and *N. glutinosa* were handled after each wash, and in every instance an occasional lesion developed on *N. glutinosa* and tomatoes were infected.

Efforts were made, therefore, to find a method of washing which would completely inactivate the virus. Several mixtures of detergents and alkaline salts were tried. Best results were obtained by dipping the hands in a 3% solution of tri-sodium phosphate (hydrated) and then scrubbing the hands and nails well with soap and water.

(d) *Clothing*

Tests on workers' clothing showed that it carried TMV. To find out how long it persisted, cotton and nylon cloths were soaked in infective tomato leaf sap and dried, or were rubbed over infected leaves, and tested at intervals. Soaked fabrics were still infective after eight months. Clothing wiped over leaves remained infective for up to seven months.

Many tests were made on washing these cloths at temperatures between 64—86° F. Several concentrations of three proprietary detergents were used, with or without washing soda or tri-sodium phosphate. Only solutions containing at least 1% tri-sodium phosphate, either alone or with detergent, eliminated TMV.

Preliminary experiments on the effect of several treatments on the TMV content of tomato seed (R. Howles)

Tomato seed of the variety 'Potentate', harvested in 1958, was fermented for five days, the seeds completely separated and all small ones discarded. Twenty grammes of the remainder were thoroughly mixed and samples checked for uniformity of TMV content by half-leaf inoculations to *Nicotiana glutinosa*.

Two-gram portions of seed were given respectively the following treatments:—

(i) soaking in 75 ml. 10% hydrochloric acid for 18 hours.

(ii) soaking in 75 ml. 10% tri-sodium phosphate for 6 hours.

(iii) soaking in 32 ml. saturated 2-chlorophenoxyacetic acid for 6 days.

(iv) soaking in 32 ml. water for 5 days.

(v) heat treatment in air at 61.5° C. for 22 days.

The seeds were rinsed and dried after treatments (i), (ii) and (iii), and dried after treatment (iv).

The TMV content of samples of seed from each treatment was determined by comparing the number of local lesions produced on half leaves of *N. glutinosa* with the number given by the same quantity (180 seeds macerated in 10 ml. water) of untreated seed (Table I). Germination, cotyledon length and seedling dry weight for each treatment are also listed in the Table. All seedlings were of normal appearance.

Some of the treatments were repeated on similar two-gram portions of 1959 seed, followed in each case by soaking the seed in water until the radicle had just appeared. Table II shows the TMV content, measured as in the previous test.

All treatments decreased the amount of infective TMV in the seed samples compared with that of the control samples, and the reduction was greater when the treatment was followed by soaking the seeds in water; but none of the treatments totally eliminated TMV from the treated seed, and some greatly reduced seed germination.

Cucumber stunt mottle disease (M. Hollings—completion of work from Harpenden)

A severe disease that completely destroyed cucumber plants in about twelve glasshouses on a Cheshire nursery was found to be caused by an unusual strain of raspberry yellow dwarf, now correctly known as arabis mosaic virus; the disease and the virus strain were called cucumber stunt mottle. When isolated from the affected cucumber plants, cucumber stunt mottle (CSM) virus would not infect any of the solanaceous species that were readily infected by two strains of raspberry yellow dwarf virus (RYDV), but after passage through *Nicotiana clevelandii* the virus readily infected nearly all solanaceous plants tested.

Experimental infection of cucumber seedlings from *N. clevelandii*, *Phaseolus vulgaris* or from the original infected cucumber specimens reproduced the symptoms of the original disease: a systemic mottle developed 2—3 weeks after inoculation, rapidly becoming severe. Expanding young leaves were dwarfed, distorted and apical growth almost ceased. Root development was very poor, and affected plants were a total loss.

The properties of CSMV *in vitro* were similar in general to those of arabis mosaic and the RYD viruses. An antiserum to CSMV, made by injecting partially purified preparations into rabbits, reacted specifically with concentrated preparations of CSM and RYD viruses in precipitin and gel-diffusion tests. CSMV protected some plants from subsequent infection with RYDV, but not against infection with strains of either tomato black ring or anemone necrosis viruses. CSMV was eliminated from both the treated rootstocks and from the small cuttings taken from them immediately after treatment, when infected tobacco plants were kept at 99° F. for three weeks. CSMV could be precipitated from clarified infective sap by several agents: material precipitated by ammonium sulphate (40% saturation) retained nearly half the original infectivity, whereas that precipitated by 60% Ethanol contained only about 1% of the initial infectivity. The virus infected 42 out of 72 plant species by mechanical inoculation, and caused symptoms in 23. Diagnostic symptoms developed in petunia and *Digitalis purpurea*. *Gomphrena globosa* was satisfactory for local lesion assay.

Although the RYDV strain of arabis mosaic has been shown to be transmitted in the soil by a nematode, no infection by CSMV was obtained when cucumber, pea or turnip seedlings were grown in samples of soil from the affected glasshouses.

Pelargonium leaf curl (M. Hollings—completion of work from Harpenden)

Symptoms of leaf curl disease of pelargonium are usually manifest only during the winter months. Pale green spots on the younger leaves soon become yellow, star-shaped necrotic lesions, and result in leaf buckling, distortion and "shot-hole" effects where necrotic areas of the leaf fall out. The American name "Crinkle" is more descriptive of the symptoms. For many years the disease has been thought to be transmissible only by grafting.

A virus consistently isolated from pelargoniums showing typical symptoms of leaf curl disease infected 51 out of 95 plant species by mechanical inoculation. Diagnostic symptoms occurred in *Chenopodium amaranticolor*, *Phaseolus vulgaris* and *Antirrhinum majus; Chenopodium*, *Phaseolus* and *Gomphrena globosa* were suitable plants for local lesion assay, and the virus was satisfactorily cultured in *Nicotiana clevelandii* at all seasons. Symptoms of leaf curl were produced in pelargoniums inoculated during the autumn and winter months (but not at other times) from infected *N. clevelandii* plants, but direct transmission from pelargonium to pelargonium was possible only by grafting. Leaf curl virus failed to maintain itself in many infected pelargonium plants during the summer months when glasshouse temperatures rarely fell below 70° F., and was

readily eliminated when infected pelargonium or *N. clevelandii* plants were grown at 99° F. for four weeks and small cuttings were subsequently taken from the tips of young shoots. This should enable healthy clones of valuable varieties that are badly affected to be reclaimed.

Partially purified preparations of the virus contained small, spherical particles when examined at Rothamsted under an electron microscope; this virus was very stable *in vitro*, and could be partially purified in several ways. An antiserum was prepared, and comparative serological tests made with isolates of leaf curl virus from several different parts of the country; the different isolates were serologically indistinguishable in precipitin tube and gel-diffusion slide tests, but one isolate was more virulent and invaded *Gomphrena* systemically far more readily than did others.

Although PLCV was similar in many ways to carnation ringspot and tobacco necrosis viruses, and to a virus from white clover, all these were serologically unrelated, and did not protect against one another in plants.

Lupin viruses (R. Howles and M. Hollings)

Nearly all the plants in the Lupin Trial at the Royal Horticultural Society's Gardens at Wisley showed leaf symptoms suggestive of virus infection when visited in June 1959.

Leaf samples from six lupin varieties were tested by mechanical inoculation to tobacco ('White Burley'), *Nicotiana glutinosa*, *Chenopodium amaranticolor*, *Gomphrena globosa*, *Tetragonia expansa*, *Phaseolus vulgaris* ('Prince') and *Vicia faba*. Lucerne mosaic and pea mosaic viruses were detected from two lupin varieties: 'Lilac Time', which showed irregular, brown necrotic streaks and flecks on the older leaves, and a chlorotic speckle-mottle on the younger leaves; and 'Thundercloud', which grew poorly and had a severe chlorotic speckle-mottle on the younger leaves and some necrotic flecks and streaks on the older leaves. Pea mosaic was also detected from three other varieties: 'Aristocrat', 'Betty Astell' and 'Freedom'. The symptoms on 'Aristocrat' and 'Betty Astell' were faint chlorotic spots and rings, principally on the younger leaves. Variety 'Freedom' had, in addition, more severe yellowish flecks, leaf distortion, buckling and dwarfing.

Inoculations from the original lupin material to seedlings of *Lupinus hartwegii* and Russell lupins caused only relatively slight systemic veinal mottle on the younger leaves. One of the *L. hartwegii* plants inoculated from the variety 'Lilac Time', however, was severely dwarfed and had crinkled leaves.

Further inoculations from *Vicia faba*, infected with the virus from variety 'Betty Astell', to pea ('Onward'), French Bean, *Trifolium pratense*, *T. incarnatum* and *Glycine max*, detected only pea mosaic virus.

Inoculations from an un-named variety (Trial no. 14), which had chlorotic veinal flecks on the younger leaves, did not detect any virus.

Narcissus viruses (L. Broadbent)

The Narcissus Trial at the Royal Horticultural Society's Gardens at Wisley was inspected twice, and severely affected plants were rogued for the eighth successive year. Plots of narcissi showing different types of virus disease symptoms have been established at the Institute, and stocks of seedlings are being grown for future work on these viruses.

Primula viruses (L. Broadbent and M. Hollings).

It is possible that the disease that has been prevalent in the Primula Trial at Wisley and in many municipal parks (see Mycology Department Report, page 59) is caused by a virus, but so far none has been demonstrated. Cucumber mosaic virus often infects *Primula* species, but is not the cause of this disease. Tobacco necrosis virus has been isolated from the roots of some plants, and a ringspot-type of virus has been found once. Field trials on the time and pattern of spread of the disease are being done at the Institute and at Wisley.

Celery (M. Hollings—conclusion of work from Harpenden)

Five different viruses were isolated from celery plants showing different kinds of symptom.

1. *Cucumber mosaic virus* was isolated several times from plants showing diffuse chlorotic leaf mottling, and sometimes diffuse, sunken brown necrotic streaks within the leaf-stalks. Damage was not severe, though infected plants were less vigorous than normal ones. Symptoms were reproduced in two varieties of celery; the diffuse mottle proved more damaging during winter than summer, but even then almost normal growth developed several weeks after infection. The virus was readily transmitted by *Myzus persicae*, and was eliminated from tobacco plants kept at 99° F. for 4½ weeks.

2. *Lucerne mosaic* was found in celery plants with yellowish rings and flecks irregularly distributed on the younger leaves. These symptoms were reproduced on two varieties of celery 4—6 weeks after inoculation with LMV; the disease was not severe, although some rugosity and puckering of the leaves occurred. The virus was readily transmitted by *M. persicae*.

3. *Celery yellow vein.* A virus, serologically related to tomato black ring, was constantly associated with characteristic symptoms in celery crops on a holding in Suffolk; sharply-defined, broad yellow bands followed the outline of the major veins of the leaves, and there was slight to moderate leaf distortion. The disease occurred in patches in the same field in successive years, and celery and other plants were readily infected when grown in soil samples from beneath affected plants. No fungal or bacterial pathogen was found, but although the virus was readily transmitted by mechanical inoculation to celery and to many other species, it never reproduced the original symptoms in celery. Experiments designed to detect any additional viruses of a complex, or particular conditions necessary for symptom development, failed to do either: infection by grafting, insect transfer, soil infection or combinations of these, at different stages of plant growth and under different conditions of season, temperature and light, all resulted in infection without symptoms. Naturally-infected soil from the celery holding retained infectivity for over two years, but all infectivity was destroyed when soil was (i) dried on the laboratory bench for two weeks, (ii) heated to 70° C. for 10 minutes or (iii) watered with Metasystox solution. The virus protected partially or fully with strains of TBR and beet ringspot viruses, and though reacting well with antiserum to beet ringspot, celery yellow vein was not itself antigenic when infective preparations were injected into rabbits.

4. *Celery yellow spot.* This was apparently the most common disease in celery crops in 1957 and 1958; inoculations failed to demonstrate any differences between isolates showing similar symptoms, but positive evidence of identity is slight. The symptoms comprise sharply-defined yellow or pale green rings, stellate spots, irregular flecks and dots on nearly all leaves of affected plants. Mechanical inoculations from different sources of affected celery to celery seedlings failed to transmit the disease unless cucumber mosaic virus was also present; but CMV alone, returned to celery from *Nicotiana glutinosa* plants, did not cause yellow spot symptoms.

Also, one celery plant showing typical symptoms of yellow spot but not infected with CMV, and from which mechanical inoculations to celery induced no reaction, was then infected with CMV, and four weeks later inoculations were made to healthy celery seedlings. The full symptoms of yellow spot developed on three of the six inoculated plants. Mechanical inoculation of 55 species of plant from affected celery containing CMV also, caused only symptoms indistinguishable from those of the same isolate of CMV alone. The severity of yellow spot symptoms increased after affected celery plants were grown at 99° F. for 3½ weeks, and the disease was not eliminated from any. Although the CMV present was readily transmitted by *Myzus persicae*, yellow spot was not.

This virus in some ways resembles the yellow spot virus disease described in the United States; American workers were unable to infect celery plants from celery, only from certain naturally-infected wild plants, but the possible influence of CMV on the transmission of their virus was not studied.

5. *Celery yellow net.* Affected celery plants had bright yellow flecks and bands sharply defined along the major veins, and less pronounced yellowing of the minor veins to produce a yellow-netting effect. This was especially noticeable in the early stages of symptom expression. Growth of the yellowed areas was much reduced, causing severe buckling and distortion of affected leaves. Characteristic symptoms also developed on the petioles: chlorotic spots, appearing in the early stages of infection, developed to brown, necrotic pits and streaks that extended along the leaf stalks, killing the outer leaves and eventually affecting the crown and killing the plant. Intensity of symptoms differed in different plants infected by sap inoculation from affected celery leaves. Some plants were very stunted and rapidly killed, while others developed less severe chronic symptoms of yellow leaf flecks, with slowly spreading petiole necrosis, and remained alive for several months.

The virus was transmitted only during the winter months, and even then the proportion of celery plants infected was often small. Out of 67 plant species tested only four (celery, parsley, carrot and *Apium repens*) were infected; symptoms on the three latter species were slight. Celery yellow net was not transmitted by *M. persicae*, nor by growing healthy celery seedlings in soil from around the roots of naturally-infected celery plants.

Transmission was too erratic for reliable assay of *in vitro* properties of the virus, but no infections were obtained when celery sap was diluted more than 1/100, heated for 10 minutes to more than 45° C. or kept at room temperature for more than 48 hours. No specific particles could be seen in preparations from infected celery leaves when examined under an electron microscope at Rothamsted.

Miscellaneous (M. Hollings)

Crotalaria spectabilis was tested as an indicator plant for several viruses isolated from gladiolus, narcissus, sweet pea, lupin and other legumes. Diagnostic reactions occurred with lucerne mosaic, broad bean mottle, pea mosaic, and a virus from narcissus that resembles bean yellow mosaic.

Pea mosaic virus was isolated from sweet pea showing leaf mottling and necrotic stem streaking; but when returned to sweet pea seedlings from *Nicotiana clevelandii* it caused only leaf mottling and very slight stem streaking. Pea mosaic has not hitherto been regarded as a cause of streaking in sweet pea, but yellow bean mosaic (which appears to be the commonest cause of streaking in sweet pea in England) could not be detected.

Two dahlias, showing typical symptoms of dahlia mosaic and in which neither cucumber mosaic nor tomato spotted wilt virus could be found, were used as virus sources in attempts to infect *Verbescina encelioides*. Successful inarch bottle-grafts from dahlia could readily be made to *Verbescina*, and aphid transfers (*Myzus persicae*) and mechanical inoculations with phosphate buffer, alumina and "Celite" added to the inoculum, were also done; but no symptoms of any kind developed on the *Verbescina* plants, although this species has been reported as an indicator plant for dahlia mosaic in the United States. It is possible that either the strain of *Verbescina* or some examples of the virus called dahlia mosaic in England may differ from those found in the United States.

Studies on the relationships between different strains of cucumber mosaic virus showed that although most strains protected against one another in Burley or Havana tobacco plants during the summer months, when also some protected against aspermy virus, protection was sometimes less complete between strains of CMV during the winter months, when most isolates of CMV failed to protect against aspermy virus. One of the CMV strains studied was a Wisconsin isolate, and although it shared many properties with English strains of CMV, such as symptoms and host range, it more closely resembled Price's yellow strain (also from the United States) and was not eliminated from some plants by heat treatment.

An antiserum prepared against aspermy virus reacted well with partially purified preparations of different strains of aspermy, but only very slightly when tested with similar preparations of certain strains of cucumber mosaic, suggesting that these strains were not closely related to aspermy.

Techniques

Freeze-drying of plant viruses (M. Hollings—completion of work in collaboration with R. A. Lelliott, Plant Pathology Laboratory, Harpenden)

Cultures of 46 isolates of 39 plant viruses were freeze-dried on an Edwards Model L.5 centrifugal freeze-dryer. Virus preparations, consisting of crude sap to which had been added 7% w/v peptone and 7% w/v glucose, were placed in ampoules (usually 0.25 ml. per ampoule) and freeze-dried. The ampoules were sealed under vacuum and stored at room temperature. The contents of an ampoule were re-constituted by adding 1.5 ml. M/15 phosphate buffer (*p*H 7.0) and tested for infectivity by inoculation to appropriate indicator plants.

Preparations of all viruses were tested for infectivity immediately after drying and again at intervals of two to eleven months; all but one (potato virus A) were successfully preserved in this way. Tests immediately after drying showed that the infectivity of those viruses with spherical particles was very high, usually similar to that of freshly-expressed sap, but many of the viruses with rod-shaped particles lost much infectivity during the process.

Although no accurate quantitative data were obtained, there seemed to be no subsequent loss of infectivity during storage.

Freeze-drying has previously been used for the preservation of bacteria and some animal viruses, but the method has many uses in plant virus work: stock cultures of many viruses can be kept in a very small space at room temperature with no danger of contamination; the viruses are unlikely to suffer changes by mutation or attenuation, which often happens when they are cultured for long periods in plants in experimental glasshouses. Inocula of uniform infectivity are available for use over long periods, and the cultures are suitable for sending long distances through the mail.

Rapid serological tests for carnation mottle and ringspot viruses (M. Hollings)

Serological tests for plant viruses give a specific identification which is of particular value where mixtures of viruses are present in a plant. For most kinds of test the plant sap must first be clarified, but with the gel-diffusion method no elaborate apparatus is required, and only one or two drops of crude sap are needed for each test. The result is known in 4—24 hours, and large numbers of plants can be indexed in a small space. The method has been successfully applied to many of those viruses having spherical particles but, apart from TMV, is generally unsatisfactory with viruses having long rod-shaped particles.

The technique is based on that of van Slogteren (1955), modified by Mansi (1958): 1 ml. of 0.8% Ionagar (Oxoid) is pipetted on to an area 40 mm. × 28.5 mm. on each microscope slide and, when solidified, wells are cut out with cork borers. The wells are 5 or 8 mm. in diameter, and 1—2 mm. apart. About two drops of antiserum to carnation mottle and ringspot viruses respectively are placed in two of the wells, and drops of crude sap from young carnation leaves placed in the central well. The slides are then incubated in moist petri dishes at room temperature.

A positive reaction, visible as a sharp line between the sap well and its appropriate serum well, is often visible within 4 hours, and reaches its maximum intensity within 24 hours (Plate II).

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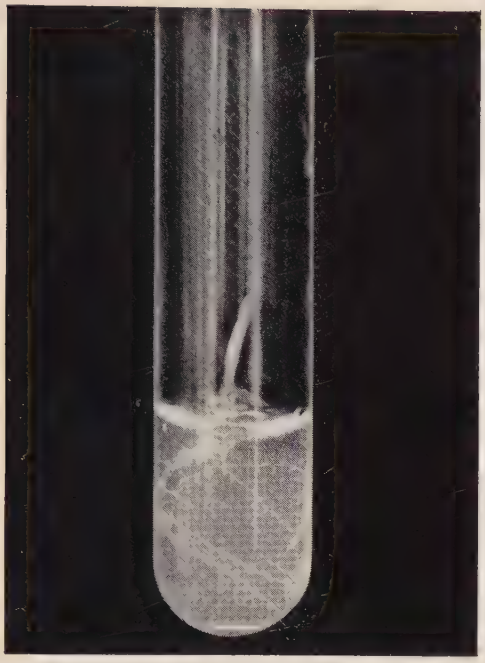

PLATE I.

CARNATION TIP CULTURE

Explant tip of 'White Sim' carnation after 14 weeks in culture tube.

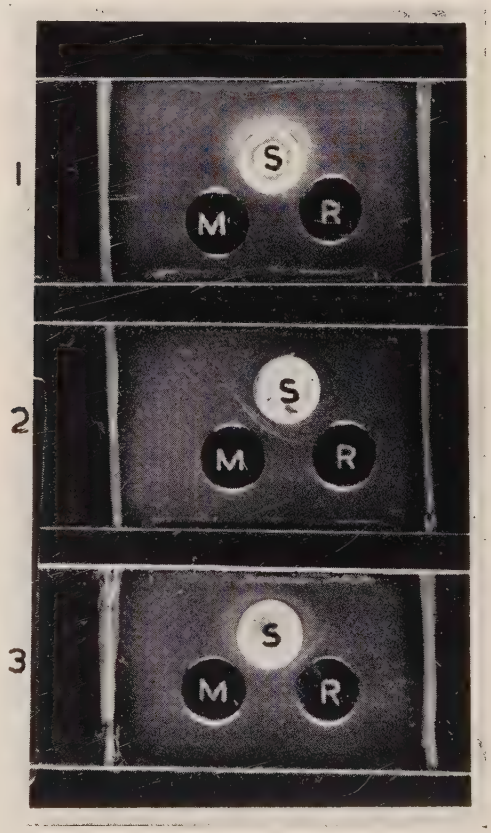

PLATE II.

GEL-DIFFUSION SLIDE TEST FOR CARNATION VIRUSES

Wells marked "M" contain antiserum to carnation mottle virus, wells "R" contain antiserum to carnation ringspot virus, and wells "S" contain sap from the carnations under test. The sap in slide 1 is from a healthy carnation, in slide 2 from a carnation infected with mottle virus and in slide 3 from a carnation infected with ringspot.

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TABLE I

THE EFFECT OF DIFFERENT TREATMENTS ON THE TMV CONTENT AND GERMINATION OF INFECTED TOMATO SEEDS

Treatment	Number of lesions on *N. glutinosa*		De-crease (%)	Seed germination (%)		Cotyledon length (cm)		Seedling dry weight (g)	
	T	U		T	U	T	U	T	U
Hydrochloric acid	*100	436	77	31	100	1.65	1.30	0.007	0.006
Tri-sodium phosphate	207	385	46	—	—	—	—	—	—
2-chloro-phenoxy-acetic acid	*160	614	74	36	100	1.90	2.0	0.004	0.006
Water	118	531	78	82	100	2.25	2.20	0.011	0.010
Heat	*213	653	67	100	100	1.5	1.3	0.008	0.006

*Combined results from four experiments; remainder from three experiments.

T—treated U—untreated

TABLE II

EFFECT OF SEED TREATMENTS FOLLOWED BY SOAKING SEEDS IN WATER UNTIL EMERGENCE OF THE RADICLE

Treatment	Duration of soaking	*Local lesions from:		Decrease in lesions (%)
		treated	untreated	
Hydrochloric acid	2 days	13	241	95
Water	6 days	45	460	90
Heat	7 days	38	284	87

*Combined results from three experiments

8. CROP PROTECTION

by

W. H. READ

Work has continued on some of the major problems of pest and disease control confronting the glasshouse industry, such as the prevention of losses of tomato plants from Stem Rot caused by *Didymella lycopersici*, and the control of Glasshouse Red Spider Mite and Cucumber Mildew. In addition several new investigations have been commenced.

The first of a series of comparative trials to compare sodium N-methyldithiocarbamate with chloropicrin and steam for the sterilisation of glasshouse soils was made in houses C1 and C2, and laboratory investigations have been made to obtain information on the break-down of this compound in the soil.

The problem of damage to narcissus foliage resulting from the application of copper sprays to control certain leaf diseases is being examined, and means of preventing copper damage, or effective safer fungicides, are being sought. This work is likely to take a number of seasons and requires the construction of a certain amount of specialized equipment. The improvement of methods for maintaining humidity in a glasshouse is also required for investigations on the control of Petal Blight of chrysanthemums (*Itersonilia perplexans*).

Chemical soil sterilisers (Sodium N-methyldithiocarbamate) (J. T. Hughes and W. H. Read)

Investigations of the problems connected with the use of sodium N-methyldithiocarbamate (for which the coined common name metham-sodium is likely to be adopted) were commenced at the end of 1958 and are continuing. An account of a trial in which this compound, chloropicrin and steam were compared is reported in a separate paper later in this Report (page 105). The trial was carried out in two adjoining glasshouses where there was no evidence of any serious soil disease or pest in the 1958 crop but where soil sterilisation was judged desirable from the lack of vigour in the plants. Examination of the roots of the tomato plants removed at the end of the 1958 season was undertaken by the Mycology Department, and it was found that whereas some *Colletotrichum atramentarium* was present on the roots of many plants it was not as abundant as might have been expected. The soil fauna was examined by the Entomology Department at the same time, also after the sterilisation treatments, and again at the end of the 1959 season; the results will be published later.

Full details of the response of different tomato varieties to the treatments and the effects on fruit quality await the results of statistical examination, but under the conditions of the experiment metham-sodium and chloropicrin were not significantly inferior to steaming in increasing the yield of tomatoes.

The chemical soil sterilising agents caused no damage in this trial, but in view of the damage which resulted from the use of products containing metham-sodium on a number of commercial nurseries the problems arising from its use are being investigated. For the furtherance of this work methods for estimating metham-sodium and also methyl *iso*thiocyanate, the latter being the most important product produced by the hydrolytic decomposition of metham-sodium, were devised, and this preliminary work is described in detail in a separate paper in this Report (page 108).

The analytical method described has been used in investigations of the rate of decomposition of metham-sodium in aqueous solutions, soil extracts and soil. It appears that the decomposition of the compound may be very greatly accelerated when aqueous solutions are brought into contact with soil, although aqueous soil extracts may not have such a marked effect.

Experiments with methyl *iso*thiocyanate have shown that low concentrations of its vapour in the air have marked effects on the growth of tomato plants, and that traces remaining in the soil are very injurious to tomatoes, cucumbers and lettuces. The possibility that methylthiourea might result from the reaction between ammonia, produced as a result of sterilising a soil rich in nitrogen, and methyl *iso*thiocyanate, and that this compound might be highly phytotoxic to plants, appears very unlikely, as both *sym.* dimethylthiourea and methylthiourea are very much less phytotoxic than methyl *iso*thiocyanate.

Investigations on the control of foliage diseases of narcissus (J. T. Hughes, W. H. Read, Pauline Smith and R. J. Smith)

(a) *Problems of spray damage and fungicide retention.* Investigations were commenced on problems associated with the control of foliage diseases of narcissus. Considerable losses may be caused by such diseases in certain areas. Sprays containing copper, although effective against several of the diseases, may be highly injurious to the plants under certain climatic conditions, particularly to some widely grown varieties susceptible to Leaf Scorch (*Stagonospora curtisii*), while zineb sprays may fail to give consistently satisfactory results.

Susceptibility to damage by fungicides may be due to many factors, a number of which are being investigated, but much of the work so far has been of an exploratory nature in order to devise satisfactory techniques. Determinations of the amounts of cuticular wax on the leaves have shown that there are considerable varietal differences, but further work is necessary to establish the importance of this cuticular wax in conferring resistance both to infection by fungi and damage by applied fungicides.

(b) *The control of Narcissus Leaf Scorch.* Work is in progress on the examination of a number of possible alternatives to copper or zineb fungicides for the control of Narcissus Leaf Scorch (*Stagonospora curtisii*), and suitable techniques for testing fungicides against this disease are being developed.

Fungicides: derivatives of halogenated salicylaldehydes (R. J. Smith)

The investigation of the fungitoxic activities of a number of halogenated derivatives of N-aryl, N-heterocyclic and N-alkyl salicylideneimines synthesised in the laboratory was concluded towards the end of the year. The original object of this work was to combine the halogeno-salicylidene nucleus of known fungicidal potentiality within a molecule containing two phenyl or halogenated phenyl groups linked by an azomethine bridge, in an attempt to obtain compounds toxic to both fungi and mites, and thus obviate the need for separate treatments to control Red Spider Mite and co-existent foliage diseases.

Although several of the compounds tested in 1958 and 1959 had marked protective action against Cucumber Powdery Mildew (*Erysiphe cichoracearum*) their eradicative properties against this fungus were inferior to those of 3-chlorosalicylideneaniline and its 3-bromo analogue, which were referred to as compounds A and B in comparative trials described in the 1958 Annual Report.

Certain nitro, chloronitro and dinitro derivatives of salicylanilide and some N-substituted salicylideneimines have also been synthesised and tested against Cucumber Powdery Mildew. The nitro derivatives of salicylanilide were phytotoxic at effective concentrations, and the nitro derivatives of certain salicylideneimines (e.g., 3:5-dinitrosalicylidene-*n*-heptylamine) were inactive as eradicants of Cucumber Mildew.

These compounds were also tested against Tomato Stem Rot (caused by *Didymella lycopersici*) by applying them in pastes to lesions produced by inoculating the stems of tomato plants with the fungus. None of the compounds proved effective in arresting the development of the lesions.

Although certain of these compounds were found more toxic than salicylanilide to spores of Tomato Leaf Mould (*Cladosporium fulvum*) when assayed *in vitro* by the test tube dilution/spore germination method, they were not more effective, at non-phytotoxic concentrations, than salicylanilide when trials were made on tomato plants in a glasshouse.

Tomato Stem Rot (*Didymella lycopersici*) (W. H. Read)

Further experiments have been made on the control with captan of *Didymella* Stem Rot of tomatoes arising from the presence of the causative fungus in the soil. These tests are described in more detail in a separate paper in this Report (page 112). The results show that on this occasion treatment of tomato plants with 3 fluid oz of 0.25% captan one day before planting from pots did not give better control than treatment with 4 fluid oz of 0.25% captan one day after planting in the borders, and the check to their growth was greater.

No evidence was obtained that protection was due to systemic action as the stems of plants grown in captan-treated soil were equally susceptible to *Didymella* as the stems of plants grown in untreated soil when inoculated, after slight abrasion, with a suspension of spores of the fungus.

Some check to the growth of tomatoes resulted from their first treatment with captan, and although, under the conditions of these experiments, this was very slight where 4 fluid oz of 0.25% captan was applied after planting, more work is required under varying soil and cultural conditions.

Suspensions of purified captan caused a slight scorching of the tips of the leaflets, and a commercial formulation of technical captan was even more phytotoxic.

Glasshouse Red Spider Mite (Valerie A. Cooke)

Trials to determine the relative values of a number of newer systemic compounds for the control of the Glasshouse Red Spider Mite (*Tetranychus urticae* Koch) on carnations have been made in which the systemic compound was applied as a drench to the soil. The primary object of these trials was to determine the period of effectiveness of the systemic compounds, both in the leaves of the growing shoots and in the older leaves.

Demeton methyl was used as the standard with which the other compounds, O.O.-diethyl-S-(ethylthiomethyl) phosphorothiolothionate (I), O.O.-dimethyl-S-(N-methyl carbamoylmethyl) phosphorothiolothionate (II), O.O.-dimethyl-S-(morpholino-carbaminylmethyl) phosphorothiolothionate (III) and 2-carbomethyoxy-1-methylvinyl-dimethyl phosphate (IV) were compared, as demeton methyl was considered the most satisfactory product for the control of Red Spider on carnations as a result of trials in 1955, and has become widely adopted for this purpose.

The systemic compounds were watered on to the soil of carnations growing in six-inch pots, 50 ml. of the diluted compound being applied per plant. Three dilutions, 0.04%, 0.02% and 0.01% of each compound were used, and there were four replications of each treatment. The plants were grown in a standardised compost and were carefully selected for uniformity of growth at the commencement of the trials. Normal cultural conditions were observed.

Two trials were made; the first was commenced in February to obtain results during a period which was relatively cool and transpiration of the plants low. A second trial was commenced in June; consequently, as the summer was abnormally hot and dry, two widely different growing conditions were utilised. The age of the plants was 37 weeks after striking from cuttings in the first trial and 56 weeks in the second trial.

The toxicities of the plant tissues to the mites were determined by placing newly emerged adult female mites on both old leaves and on the young leaves of the growing shoots, at intervals, and recording the mortality of these six days later. The infested shoots were kept from contact with other parts of the plants by polythene sleeves, open at the one end to prevent any abnormal effects due to vapour action.

The results of the first trial showed that although demeton methyl gave the most rapid response it was not as persistent as (I) applied at the same rate, and at the peak of its effect did not make either young or old leaf tissues as toxic to the mites as the latter compound. Compound (II) was intermediate between these two in its speed of action and in the mortality it caused at the peak of its effect. Compounds (III) and (IV) failed to give a mortality exceeding 25% on either young or old growth under the conditions of this trial.

As was expected, the effect of the higher temperatures during the trial which started in June was to decrease the period between application and the development of maximum toxicity, to increase the maximum toxicity induced in the plants and to reduce to some extent the persistence of the compounds.

The prolonged period over which the tissues of carnations were made sufficiently toxic to give 100% mortality of adult female mites feeding on them over a period of six days was again demonstrated by (1). This compound is not generally available in Britain and has the disadvantage of high mammalian toxicity, but if its use as a soil treatment on carnations and possibly other ornamentals in glasshouses is not regarded as too hazardous, it appears to show considerable merit.

Both demeton methyl and (II) have the advantage of relatively low mammalian toxicity, although they are considerably less persistent than (I). The other compounds, one of which is possibly too hazardous for use in glasshouses, do not appear promising when applied as soil drenches.

9. HORTICULTURE

by

G. F. SHEARD

The Horticultural Department was established on 1st May with the appointment of Mr. G. F. Sheard as Head of Department. The work of the Department will be concentrated on the field application of research and the investigation and development of new cultural techniques. With the appointment of Mr. A. C. Bunt (October 1st) work has begun on plant density studies with carnation, and on loamless composts.

Mr. Sheard has been primarily concerned with planning the re-organisation of the heating system in the field trial glasshouses, and the execution of this work will occupy a considerable proportion of his time until early 1961.

In addition to duties in the Department, Mr. Sheard will undertake the duties of Scientific Liaison Officer.

III. SPECIAL RESEARCH REPORTS AND REVIEWS

1. A NOTE ON THE GRADING OF UNEVENLY COLOURED TOMATO FRUIT FROM THE MANURIAL TRIALS DURING 1959

by

G. W. WINSOR

As is only too well known to the grower, tomatoes are very prone to show uneven ripening. This irregularity of pigmentation, sometimes accompanied by more serious defects such as "internal browning" and pitting of the walls, may take many forms. The proportion of unevenly coloured fruit varies enormously with variety, season and cultural (including manurial) conditions, as well as with the severity of the grading; it is no exaggeration to state that, if uniform coloration is strictly defined, the proportion of uniformly coloured fruit may under some conditions become relatively small, though fortunately many of the milder instances of uneven pigmentation appear to be acceptable commercially.

It is probably true to say that, until the causes and mechanism of the various ripening disorders are more fully understood, a truly satisfactory basis for the grading of non-uniformly coloured fruit for the purposes of research is unavailable. In the absence of any such background, a complex classification based on the different forms of uneven pigmentation in terms of colour, form and position was developed by Dr. Cooper, of this Institute (1). To facilitate work on a larger scale a simplified fruit grading scheme was also drawn up, based on the frequency of occurrence of the different types of uneven pigmentation.

During recent years, when the problems of abnormal ripening of tomatoes have been receiving much attention here in several Departments, and whilst the highly desirable aim of adopting one unified grading scheme for use both at the Institute and in external trials has been much discussed, the basic grading scheme applied to fruit from the manurial trials has been kept very simple (2); although supplemented on occasions by more detailed sub-classification, fruit showing irregular coloration of any kind has been classified as either slightly to moderately affected (grade C1) or severely affected (grade C2). As in all types of grading, this sub-division is entirely arbitrary and associated with some degree of error. It does, however, separate fruits which would be entirely unacceptable to the consumer from those which, though showing some degree of irregular colour, would ultimately be acceptable either wholly or in part when more fully ripened. This sub-division on the basis of severity has in fact proved most interesting, in that it is almost invariably found that the more severely affected category of fruit (C2) shows a more marked relation to manurial levels in the glasshouse trials than do the data for total non-uniformly coloured fruit (see for example the Annual Report for 1958, p. 33, Table IV).

The need for some further sub-division of the category of abnormally ripened fruit still remained, however, as may be seen from the Annual Report for 1957, p. 95, Table III, where the proportions of fruit showing different types of abnormality varied enormously with the position of the plants in the house. In practice the number of sub-grades which can be recorded is limited by the staff available, and the prime need is therefore to establish the minimum number of categories capable of giving the main information required. During 1959 an attempt was therefore made to obtain further data on the occurrence of different forms of fruit abnormality in the manurial trials as a basis for future grading. For this purpose the whole of the non-uniformly coloured fruit from the various manurial trials was carefully regraded on selected dates throughout the season,

using a scheme with 28 main categories and with numerous additional sub-categories where two types of defect were present on the same fruit; both weight and numbers in each category were recorded.

This rather complex grading scheme was never intended for routine use, and was employed solely by the author; it was thus possible to avoid the over-simplification inherent in the construction of basic grading schemes for general use by graders, and to allow classification not merely on the basis of colour and position but also on hardness of tissue and degree of severity. Such a grading scheme is inevitably cumbersome and to some extent even a matter of personal judgment, but it was felt that, in this limited context, much could be gained by using all the senses available to the operator rather than assessment on uniformity of pigmentation alone.

Outline of the grading scheme used in this study

The main features of the experimental grading scheme were as follows. Fruits showing areas of green or yellow tissue on an orange-red background (other than "hard-top" as defined subsequently) were sub-divided, into twelve categories, as green or yellow, mild or severe, and by position on the fruit ("side", "intermediate" or "top"). All such fruit in which the affected area included some tissue immediately adjacent to the calyx was classified under "top", independently of the distribution of the remainder of the affected area. Fruits classed as "intermediate" in this respect either had more than one affected area, one but not all of which extended from the calyx, or were borderline cases in which the affected area was close to the calyx but not assignable with certainty to the "top" category (such cases are not infrequent). The term "side" has been used to include affected areas anywhere on the fruit other than adjacent to the calyx. For ease of reference the term "blotchy ripening" has been used in referring to these twelve sub-categories in the results which follow.

A category referred to as "hard top", broadly equivalent to "greenback", was sub-divided as green or yellow, mild or severe (four sub-categories), and was also separately recorded where present together with other disorders. The criteria for inclusion in this grade, apart from position around the calyx, were that the affected tissue should be hard and that, if green, the colour should be deeper than that of a normal unripe tomato.

"Waxy" fruits were sub-classified as mild or severe, and also by position as "top" or "side"; as this category, though important, is not large in numbers the "intermediate" sub-grading previously referred to was here omitted.

A further category included fruits which were paler in colour at the top (i.e., around the calyx) than elsewhere, the transition in colour being without any abrupt demarcation and unaccompanied by any obvious structural defects in the walls, sub-classified by colour (green or yellow) and severity (mild or severe). These four sub-categories are quite unlike "blotchy ripening" or "greenback", and may only reflect the tendency of tomato fruit to ripen more rapidly in the regions away from the calyx. The proportion of such fruit encountered is, however, too large to be ignored when grading at the commercial picking stage unless the decision is also taken to include them with uniformly coloured fruit on the grounds that they tend to ripen up more evenly within a few days.

A separate category was provided for fruits showing the attractive deep-green shading of pigment around the calyx, unaccompanied by any hardness or structural defects (see the Annual Report for 1957, pp. 42—43 for the highly favourable analysis of such fruits, given in Tables II and III under the designation of Grade C4). Fruits showing narrow green or yellow radial areas of sharp outline were also recorded separately.

Results and discussion

The fruit for this grading study was obtained from nutritional trials in houses B1—4, C3 and 4 and D1 and 2. The results which follow are all for variety 'Potentate' grown at commercial spacings (the spacing of tomato plants appears to influence the proportion of the various forms of abnormal ripening). Fruit of variety 'Immuna' was also graded, but the results have been omitted from this report. Grading was carried out on 24 dates from May to September, and was applied to a total of 8,869 fruits showing irregular colour drawn from a total of 22,092 fruits picked on these dates. The results do not, of course, show the overall distribution of different forms of abnormality in any one crop for the entire season, but are regarded rather as a cross-section of the material handled by the graders engaged in the regular recording of the manurial trials.

Expressed as percentages of the total number of non-uniformly coloured fruit (variety: 'Potentate') graded in this study, the proportions of fruit in the main grades were as follows:

"Blotchy" fruit	38.3%
Sub-divided as "Top"	22.5%
"Intermediate"	11.5%
"Side"	4.3%
Sub-divided as Green	25.3%
Yellow	13.0%
Sub-divided as "Mild"	21.2%
"Severe"	17.1%
"Hard top"	33.4%
Sub-divided as Green	22.1%
Yellow	11.3%
Sub-divided as "Mild"	22.6%
"Severe"	10.8%
Fruit showing both "blotchy ripening" and "hard top"	3.7%
General pale top	9.6%
Sub-divided as Green	2.9%
Yellow	6.7%
"Waxy" fruit	5.2%
Sub-divided as "Top"	4.2%
"Side"	1.0%
Sub-divided as "Moderate"	2.0%
"Severe"	3.2%
Deep green shading around calyx	2.4%
Narrow radial bands	1.9%
Miscellaneous	5.6%

The data now presented form only an abbreviated summary of the totals for the season, but numerous matters arise for discussion. Even after careful separation, within the limits of experience and of our present knowledge of the various disorders, of "hard-top" ("greenback") from other forms of disorder, the category listed as showing "blotchy ripening" is almost certainly not truly homogeneous, and includes a number of mild defects not necessarily arising from one single cause. The data show that a high proportion of the fruits classed as "blotchy" include an area of the wall adjacent to the calyx among the affected tissue. This is true both for green "blotch" and for yellow "blotch", and also for both degrees of severity of disorder. Thus as percentages by number of green and yellow "blotchy" fruit respectively the proportions graded were:

	Green (2,455 fruits)	Yellow (1,274 fruits)
"Top"	56.1%	49.1%
"Intermediate"	28.8%	39.5%
"Side"	15.1%	11.4%

As percentages of the "mild" and "severe" categories of "blotchy" fruit, irrespective of colour, the corresponding proportions were:

	"Mild"	"Severe"
"Top"	47.7%	62.0%
"Intermediate"	34.8%	29.3%
"Side"	17.5%	8.7%

The results for severely blotchy fruit show an even more marked positional trend than do those for milder cases; this may well be because severe blotchy ripening is more readily classified, whereas the milder category probably includes a number of fruits not showing internal browning, the nature of which is uncertain. It may also be noted that fruit showing colourless areas in the walls ("waxy" fruit) show a still more marked positional distribution, 82% being recorded as including tissue adjacent to the calyx.

Of the fruit showing areas of hard tissue around the calyx, generally referred to as "greenback", at the commercial picking stage adopted at the Institute during the very bright summer of 1959 approximately two-thirds was classified as green and one-third as yellow, though the colours were rarely pure and the green areas tended to become yellow as they ripened. In view of the considerable proportion of fruit showing hard yellow areas in this category, it is suggested that the term "hard-top" is preferable to "greenback". Furthermore it is of some practical importance to attempt to distinguish yellow forms of "hard-top" from yellow "blotch".

No less than 9.6% of the total non-uniformly coloured fruit showed some general loss of colour at the top (i.e., around the calyx) without abrupt demarcation or structural fault. This can hardly be regarded as a major fruit defect, but nevertheless the grader is confronted with an appreciable proportion of such fruit which can be difficult to classify under simplified grading schemes.

The "miscellaneous" category, amounting to 5.6% of the total graded fruit, included a wide range of irregular pigmentation and other defects. A number of fruit having an obviously immature green locule in a multi-locular fruit was included under this heading, together with fruits showing the abnormal pigmentation associated with rough skin texture.

Being drawn from several different manurial trials, the fruit grading records now described are insufficient to give fully representative data for any single experiment, but examination of the results is nevertheless of interest. Thus for the magnesium deficiency trials in houses D1 and D2, from which a total of 1,639 non-uniformly coloured fruits drawn from a total pick of 3,848 fruits was regraded on four occasions during the season, the following results may be summarized; all values are expressed as percentages by number of the total pick on these four dates:

	Low potash	*High potash*
Non-uniformly coloured	57.4%	28.1%
"Hard-top"	20.0%	8.8%
"Blotchy" fruit	27.7%	12.2%
Sub-divided as "mild"	15.9%	10.4%
"severe"	11.8%	1.8%
"Waxy" fruit	3.4%	0.7%

Thus the simple grading of non-uniformly coloured fruit was sufficient to show a marked improvement in fruit quality at the higher level of potash, and the incidence of both "hard-top" and "blotchy ripening" has been influenced by manurial levels. The most striking feature, however, is that, whereas the proportion of fruit showing severe "blotchy ripening" was very much reduced at the "high" level of potash, the occurrence of minor areas of yellow or green tissue in the walls (here included as "mild blotch") was far less responsive to manurial levels.

The corresponding data for the liquid feeding trial in house C4, based on a total pick on seven dates of 5,780 fruit, of which 2,448 were non-uniformly coloured, is as follows:

	Potash/nitrogen ratio (K_2O/N)			
	1.0	*1.5*	*2.0*	*2.5*
Non-uniformly coloured	49.4%	44.1%	39.3%	37.4%
"Hard-top"	21.8%	20.7%	18.0%	18.9%
"Blotchy" fruit	18.8%	15.7%	14.6%	12.1%
Sub-divided as "mild"	11.1%	11.2%	10.1%	10.2%
"severe"	7.7%	4.5%	4.5%	1.9%
"Waxy" fruit	2.3%	2.6%	1.7%	1.0%

In this trial the level of potash even at the lowest potash/nitrogen ratio is fully sufficient to eliminate any visual symptoms of deficiency, and the response to additional potash was less marked but still evident in the data for total non-uniformly coloured fruit. The proportion of fruit showing "hard-top" was only slightly decreased at the high potash/nitrogen ratios, and the total percentage of "blotchy" fruit only fell by about one-third from the lowest to the highest ratio. Sub-division in terms of severity, however, shows that, whereas the proportion of mildly "blotchy" symptoms was virtually independent of the treatments, the proportion of severe "blotchy ripening" was very markedly reduced. An interesting positional effect in the glasshouse was also revealed. In this house, planted "length-ways", plots 21—24 are adjacent to the glass on the west side of the block, whereas plots 1—4 occupy a more shaded internal position on the opposite side of the house. The grading results show that, whereas the incidence of "blotchy" and "waxy" fruit was in this instance apparently unrelated to position, the proportion of "hard-top" was twice as high in the exposed plants beside the glass:

	"Blotchy" + "Waxy"	"Hard-top"
Plots 1—4 (shaded side)	19.9	15.0
Plots 21—24 (exposed side)	18.5	30.4

(% by numbers in total pick)

The results of this grading study are still being considered as a guide to the requirements of future grading schemes applied to fruit from the manurial trials. It seems highly desirable to distinguish as far as possible between "hard-top" or "greenback" and the other forms of abnormal ripening, and the presence of yellow forms of this disorder should be allowed for. Brief, lucid definitions of distinct categories for "hard-top" and "blotchy ripening" are difficult to devise, particularly as the commonest area for affected tissue in both instances is around the calyx. In "hard-top" the affected area often tends to encircle the calyx more completely than in "blotchy ripening", but this is not always the case. Some of the milder instances of irregular green pigmentation not necessarily adjacent to the calyx may even be related to "hard-top" rather than to "blotchy ripening". The green pigmentation in the commonest form of "hard-top" is considerably darker than in "blotchy ripening", and as a simplified guide to grading may be said to be deeper than the green of a typical unripe tomato; colour alone is not always a sufficient guide, however, and the hardness of the tissue is a further point of classification.

The far greater response to manurial treatment shown by data for the more severe forms of "blotchy ripening" makes the retention of this sub-classification highly desirable. The question also arises as to whether the standard for "uniformly coloured" fruit has not been too strict; the relatively small response of some of the milder categories of irregular pigmentation to different treatments may even suggest that we are dealing with the inherent natural variability of biological material rather than any definite disorder, and the tolerance limits of commercial grading may well be a more valuable guide in this respect.

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2. PRELIMINARY EXPERIMENTS IN THE USE OF LOAMLESS COMPOSTS FOR THE PROPAGATION OF ANTIRRHINUMS AND TOMATOES

by

P. J. SUTTON

The standard John Innes composts are in widespread use in commercial horticulture, and very satisfactory results are obtained when the published recommendations for their preparation are carefully followed. Unfortunately their principal constituent is turf loam of a quality which is frequently difficult and expensive to obtain, and the necessary cutting and stacking where turf itself is available are costly in labour and space. The steam-sterilisation of the loam, which is an essential part of its preparation, is expensive, and certain species, e.g., antirrhinum, *Primula sinensis*, seem very susceptible to damage when this is not carried out with considerable care; the causes of sterilisation injury still require further investigation, but manganese toxicity can certainly occur under these conditions.

For these reasons the publication in the U.S.A. during 1957 of a detailed description of composts in which sand and peat were the only constituents attracted great interest, especially as these University of California (U.C.) composts were already in extensive commercial use (1). Although it was recommended that the sand and peat should be steam-sterilised, there is a strong possibility that this would prove unnecessary under British conditions. Shortly afterwards, promising results in the raising of seedlings and the cultivation of pot plants in an unsterilised loamless compost were reported by Dempster in this country (2). The literature relating to standard seed and potting composts was reviewed in the Annual Report for 1958 (4).

In the experiments now described loamless composts of the U.C. and Dempster types were used to assess their suitability for:

(1) the germination of antirrhinum seeds, and the raising of the seedlings in seed trays up to the planting-out stage,
(2) the germination of tomato seeds and the early growth of the seedlings in seed trays,
(3) the growth of young tomato plants in pots from the pricking-out stage to the planting-out stage.

Experiment with antirrhinums

Experiment 1. Germination and growth to planting-out stage in U.C.-type composts and in JIS

There were thirteen composts in all, the U.C.-type composts 1, 2 and 3 being tested in factorial combination with four rates of addition of lime against John Innes Seed Compost (JIS) for comparison.

TABLE I

COMPOSITION OF COMPOSTS FOR EXPERIMENTS 1 AND 2

Compost	Bulk constituents (parts by volume)	Base fertilisers (parts by weight)	Liming rates
1	Sand:peat 3:1	2½ oz/bushel: KNO_3 3, K_2SO_4 2, Superphosphate 20	A 4 oz./bushel ground; B 8 oz./bushel magnesian; C 12 oz./bushel limestone; D 16 oz./bushel
2	Sand:peat 1:1		
3	Sand:peat 1:3		
4 (JIS)	Loam:sand:peat 7:2:3	1½ oz./bushel Superphosphate	¾ oz./bushel ground chalk

Preliminary microscopic examination of the sand used for composts 1, 2 and 3 suggested that it conformed approximately to the U.C. specification. Sieve analyses subsequently showed it to be slightly coarser, however; thus approximately 90% of the particles were below 0.1 inch diameter and 70% below 0.05 inch. Sphagnum peat was used for all composts. The constituents of compost 4 (JIS) also conformed to published recommendations (3). The base fertiliser dressing is one of those given for the 3:1 mixture of sand and peat in "The U.C. System" (1. *p.* 72). As in all the experiments other than Experiment 3 the loam and peat for the JIS compost and the sand and peat for the U.C.–type composts were steamed before mixing.

Four seed trays were filled with each of the thirteen composts, and 50 seeds per tray were sown of the variety 'Sutton's Intermediate Yellow' on the 19th November, 1958. The 52 trays were arranged in four randomised blocks. A minimum night temperature of 58° F. was maintained until most of the germination had taken place. The seedlings were counted 31 days after sowing, the results being given in Table II; for details of the various treatments see Table I.

TABLE II

EXPERIMENT 1: MEAN PERCENTAGE GERMINATION OF ANTIRRHINUM

Composts \ Liming treatments	A	B	C	D	Compost means
1	66.0	70.0	71.0	74.5	70.5
2	66.0	69.5	71.0	70.5	69.0
3	68.0	63.5	69.0	77.5	69.5
Liming means	66.5	67.5	70.0	74.0	
4	67.0				

The results show no significant differences between composts, but with the U.C. composts the percentage germination increased progressively with the level of lime added.

The seedlings were grown on until 13th March, 1959. The trays were watered as required, and between 6th January and 4th March all trays received five applications of the U.C. liquid fertiliser L.7 (8 oz. ammonium nitrate, 8 oz. mono-ammonium phosphate and 8 oz. potassium chloride, dissolved in 100 gallons of water) modified by the replacement of potassium chloride with potassium sulphate. No visual differences were apparent between the plants, and growth was generally vigorous. The foliage was quite dark green.

On 13th March all the plants were cut off at ground level and weighed. Mean fresh weight per plant was found to regress significantly on plant number in the tray. After extracting the regression component from the treatment sums of squares it was found that there were no significant differences between the treatments. However, differences between the means for composts 1 and 2 were very nearly significant at $P = 0.05$. When mean fresh weights per plant were corrected for plant number per tray the results were as shown in Table III.

Experiments with tomatoes

Experiment 2. Germination and growth of seedlings in U.C.-type composts and in JIS

In this experiment the composts were identical with those in the previous one (see Table I). Four standard seed trays were filled with each compost, and seeds of variety 'Stonor's Exhibition' were sown in them on 3rd December, 1958, again 50 seeds to each tray. The seedlings were counted nineteen days after sowing, the results being given in Table IV. Mean percentage germination was significantly higher in composts 2 and 3 than in 1 and 4 ($P=0.01$).

TABLE III

EXPERIMENT 1: MEAN FRESH WEIGHTS (*g*) PER PLANT, CORRECTED FOR PLANT NUMBER

Compost	Weight per plant	Liming rate	Weight per plant
1	2.42	A	2.56
2	2.83	B	2.62
3	2.55	C	2.45
4	2.72	D	2.76

TABLE IV

EXPERIMENT 2: MEAN PERCENTAGE GERMINATION OF TOMATO

Composts \ Liming treatments	A	B	C	D	Compost means
1	89.5	82.0	75.5	85.0	83.0
2	92.5	93.0	89.0	92.5	91.5
3	95.0	91.0	95.0	91.0	93.0
Liming means	92.5	88.5	86.5	89.5	
4	79.0				

Least significant differences (P=0.05):

within table (including compost 4) .. .. ±8.0
between composts 1, 2 and 3.. .. .. ±4.0
between liming treatments .. .. .. ±4.6

The trays were watered as necessary, and two applications of liquid fertiliser were given as in Experiment 1. The seedlings were cut off at ground level on 14th January, 1959, and weighed, the results being as tabulated in Table V. In this case mean fresh weights per plant did not regress significantly on plant number per tray.

TABLE V

EXPERIMENT 2: MEAN FRESH WEIGHTS (*g*) PER PLANT

Composts \ Liming treatments	A	B	C	D	Compost means
1	0.75	0.52	0.53	0.53	0.58
2	0.75	0.76	0.68	0.78	0.74
3	0.81	0.83	0.81	0.80	0.81
Liming means	0.77	0.70	0.67	0.70	
4	0.69				

Least significant differences (P=0.05):

within table (including compost 4) .. .. ±0.12
between composts 1,2 and 3 .. .. .. ±0.06

The interaction between compost and liming level was statistically significant; thus high levels of lime were unfavourable in the most sandy compost (compost 1), but did not affect the fresh weights of plants grown at the highest level of peat (compost 3).

Measurements of *p*H were made on samples of all the U.C.-type composts in Experiments 1 and 2, both directly after mixing and after the growth of plants in them, together with *p*C determinations on selected samples. The results are shown in Table VI.

TABLE VI

EXPERIMENTS 1 AND 2: *p*H AND *p*C VALUES

Compost	*p*H			*p*C		
	Initially	At end of Experiment:		Initially	At end of Experiment:	
		1	2		1	2
1A	5.23	6.22	5.77	3.58	3.59	3.40
1B	7.15	6.45	5.91			
1C	7.25	6.47	6.06			
1D	7.18	6.69	6.10	3.60	3.55	3.42
2A	4.86	5.86	5.20	3.45	3.31	3.22
2B	6.60	6.05	5.42			
2C	6.79	6.18	5.62			
2D	6.65	6.12	5.72	3.46	3.42	3.30
3A	4.05	5.23	4.88	3.27	2.97	2.98
3B	5.72	5.51	5.04			
3C	6.35	5.73	5.30			
3D	6.33	5.78	5.46	3.21	3.03	3.05

Growth of young tomato plants in pots from pricking-out to the planting-out stage

Experiment 3. Comparison of five composts formulated strictly according to published recommendations

This experiment was a simple comparative trial in which five composts were prepared and given applications of fertiliser according to their originators' recommendations. The formulae of the various composts are given in Table VII.

The sand used in Dempster's compost conformed with recommendations for that in the John Innes composts; the peat was sedge peat granulated to particles of $\frac{1}{8}$—$\frac{3}{8}$ in. diameter, and the powdered clay was obtained from a firm of flower pot manufacturers. For further details the appropriate sources should be consulted (1—3).

Seeds of variety 'Stonor's Exhibition' were sown on 12th January, 1959, in the compost 2B as used in the previous experiments (Table I). As soon as the cotyledons were fully expanded the seedlings were pricked out into $3\frac{1}{2}$ in. pots, 48 for each compost. They were then placed pot-thick in eight randomised blocks on a glasshouse bench, where from 29th January to 25th February they received $7\frac{1}{2}$ hours' supplementary irradiation per day under high-pressure mercury vapour lamps. They were roomed out to double spacing on 26th February.

The plants were watered as necessary throughout the experiment. Those growing in U.C. composts were liquid-fed a fortnight after pricking out and then twice again at ten day intervals, using the modified U.C. liquid feed L.7. An application of the John Innes "L" Feed was given to plants in JIP1 seven days before they were cut off and weighed.

TABLE VII

FORMULAE OF COMPOSTS USED IN EXPERIMENT 3

Compost	Bulk constituents (parts by volume)	Base fertiliser		Lime	
		Composition (parts by weight)	Application rate (per bushel)	Composition (parts by weight)	Application rate (per bushel)
1. Dempster's	Sand 5 Peat 4 Clay 1	Hoof and horn meal 8 KNO_3 1 Triple superphosphate 2 K_2SO_4 1	12 oz	Ground magnesian limestone	5 oz
2. J.I.P.1	Loam 7 Peat 3 Sand 2	Hoof and horn meal 2 Superphosphate 2 K_2SO_4 1	4 oz	Ground chalk	¾ oz
3. U.C."B"	Sand 3 Peat 1	KNO_3 3 Superphosphate 20 K_2SO_4 2	2½ oz	Ground magnesian limestone 18 Ground chalk 5 Gypsum 5	5¼ oz
4. U.C."C"	Sand 1 Peat 1	KNO_3 1 Superphosphate 10 K_2SO_4 1	2¼ oz	Ground magnesian limestone 3 Ground chalk 1	7½ oz
5. U.C."D"	Sand 1 Peat 3	KNO_3 1 Superphosphate 8 K_2SO_4 1	2 oz	Ground magnesian limestone 5 Ground chalk 4	6¾ oz

Throughout the experiment plants in JIP1 and U.C."C" compost were the largest and most uniform; at the end the plants in the "C" compost were judged the best in the experiment, being darker green than those in JIP1. Plants in U.C. "B" compost were fairly good, but less uniform than in either "C" or JIP1, especially in the earlier stages. In Dempster's compost the plants were poorer than those in "B", having deteriorated after rooming-out; they were of a rather pale green colour, and in some cases showed a mild chlorosis. The smallest and most variable plants in the experiment were in U.C."D" compost, and all of them were chlorotic. Compost "D" showed the highest moisture-retaining properties and tended to be rather wet early in the experiment; later, after drying out somewhat, it proved difficult to re-wet in some cases. "C" was the easiest compost to water satisfactorily, pots containing JIP1 and "B" tending to dry rapidly. Dempster's compost drained much too freely, and by the end of the experiment it had set in the pots in a hard but very porous mass; daily watering was sometimes inadequate to prevent wilting even at that time of the year.

The plants were cut off at cotyledon level on 12th March. Mean fresh weights per plant are tabulated in Table VIII. The two highest mean weights, those for plants in JIP1 and U.C."C", were not significantly different, but all other differences were highly significant.

Determinations of *p*H and *p*C were made on the composts both before and after use, and the results are given in Table IX. The poor performance of plants in U.C."D" cannot entirely be accounted for by low *p*H values.

TABLE VIII

EXPERIMENT 3: MEAN FRESH WEIGHTS (*g*) PER PLANT

Compost	Mean fresh weight (*g*)
1. Dempster's	8.0
2. J.I.P.1	13.1
3. U.C."B"	10.1
4. U.C."C"	13.4
5. U.C."D"	5.2

Least significant difference (P=0.05): ±1.1

TABLE IX

EXPERIMENT 3: *p*H AND *p*C VALUES

Compost	*p*H		*p*C	
	Initial	Final	Initial	Final
1. Dempster's	6.79	7.15	3.01	3.39
2. J.I.P.1	6.19	6.02	3.08	3.26
3. U.C."B"	5.95	6.99	3.05	3.70
4. U.C."C"	5.80	6.73	3.07	3.67
5. U.C."D"	5.86	6.33	2.89	3.28

Experiment 4. Comparison of five U.C.-type composts and a Dempster-type compost, at four liming levels

In view of the very satisfactory performance of the U.C."C" compost in Experiment 3, and the possibility that acidity was at least partly responsible for the comparative failure of plants in "D", a more thorough investigation on sand-peat composts was carried out. Account was also taken of the desirability of putting lime additions to U.C. composts on a more rational basis than appeared to be the case. The composts used for these purposes are detailed in Table X. The bulk constituents in the composts 1—5 were as described for composts 1—3 in the first two experiments, and in compost 6 as for Dempster's compost in Experiment 3. The base fertiliser was as used in Experiments 1 and 2, taken from the University of California publication (1).

TABLE X

COMPOSITION OF COMPOSTS FOR EXPERIMENT 4

Compost	Bulk constituents (parts by volume)	Base fertilisers (parts by weight)	Liming rates
1	Sand:peat 3:1	2½ oz/bushel: KNO_3 3; Superphosphate 20; K_2SO_4 2	A 4½ oz/bushel; B 9 oz/bushel; C 13½ oz/bushel; D 18 oz/bushel — ground chalk
2	Sand:peat 2:1		
3	Sand:peat 1:1		
4	Sand:peat 1:2		
5	Sand:peat 1:3		
6	Sand:peat:clay 5:4:1		

Seeds of the variety 'Potentate' were sown in U.C."C" compost on 24th February, 1959, and pricked out into 3½ in. pots (48 for each treatment) on 9th and 10th March. They were stood in eight randomised blocks, six pots per plot. Until 2nd April they were placed pot-thick, and were then roomed-out to double spacing. Two applications of the U.C. liquid feed L.7 were given, on 20th March and 1st April.

Shortly after rooming-out all plants showed symptoms of nitrogen and phosphorus deficiency and had a pot-bound appearance. U.C. liquid feed L.5 (12 oz. NH_4NO_3 and 12 oz. $NH_4H_2PO_4$ in 100 gallons of water), which has a considerably higher nitrogen and phosphate content than L.7, was applied on 8th April. By 16th/17th April, when the plants were cut off at cotyledon level and weighed, they had improved in appearance, but were still of poor quality, the older leaves being pale and many plants having dropped their cotyledons. Plants in the Dempster-type compost 6, containing clay, were generally smaller than those in the other composts, but there were no other apparent differences between treatments. Mean fresh weights per plant are given in Table XI.

TABLE XI

EXPERIMENT 4: MEAN FRESH WEIGHTS (*g*) PER PLANT

Composts \ Liming treatments	A	B	C	D	Compost means
1	17.0	15.9	16.2	15.3	16.1
2	17.0	17.5	17.3	16.4	17.0
3	17.0	17.2	16.3	17.6	17.0
4	17.9	19.4	18.3	19.2	18.7
5	19.4	18.3	19.1	19.4	19.1
6	14.5	15.3	14.4	13.3	14.4
Liming means	17.1	17.3	16.9	16.9	

Least significant differences (P—0.05):
within table .. .. ±1.0
between composts 1-6.. .. .. .. ±0.5

As in Experiment 2 there were significant increases in mean fresh weight per plant as the proportion of peat in the sand-peat composts rose. Plants in compost 6 were significantly the lightest (P=0.01). Liming itself had no significant effect on plant weight, but there was a significant interaction between liming rates and composts; thus the higher levels of liming decreased plant growth somewhat in the sandy composts but not in composts having a high peat content.

Experiment 5. Comparison of five U.C.-type composts at four liming levels and JIP2

It was decided that it would be worthwhile modifying and repeating Experiment 4, owing to the occurrence of the nutrient deficiencies. The performance of plants in the Dempster-type compost 6 had been so poor, however, that it was omitted, standard JIP2 taking its place.

The physical composition of the U.C.-type composts and rates of lime addition were as in Experiment 4 (Table X). The base fertiliser used was freely adapted from U.C. recommendations for a fertiliser for the "B" compost containing a "moderate nitrogen reserve" (1, *p.* 72), 60% more superphosphate and a third more potassium nitrate being added. Its composition was superphosphate, hoof and horn meal, potassium nitrate and potassium sulphate in the ratio 16:10:2:1 parts by weight.

Sowing took place on 21st April, 1959, and pricking out on 4th and 5th May. There were 42 pots in each treatment, arranged in seven randomised blocks. The plants were given one application of U.C. liquid feed L.7.

Symptoms as of phosphate deficiency again occurred in plants in the U.C.-type composts, despite the additional superphosphate in the base fertiliser. The deficiency symptoms became more widespread as growth proceeded, plants in the sandier composts being the worst affected. Slight chlorotic mottling was also noted in composts 2—5, especially in 4 and 5 (high peat content), and particularly at the lower levels of liming.

Plants grown in JIP2 were outstandingly the best in the experiment, being sturdy with larger, better developed and darker green leaves. The foliage of plants in all other composts was greyish-green, often tinted purple; the condition of these plants showed no signs of improvement as the experiment continued, and all plants were therefore cut and weighed on 29th May, at an earlier stage of development than in the preceding experiment. Mean fresh weights per plant, and *p*H and *p*C values in the composts, are given in Tables XII and XIII.

TABLE XII

EXPERIMENT 5: MEAN FRESH WEIGHTS (*g*) PER PLANT

Composts \ Liming treatments	A	B	C	D	Compost means
1	9.3	9.8	8.7	9.0	9.2
2	9.8	10.5	9.5	10.3	10.0
3	10.2	10.0	10.3	10.6	10.3
4	10.0	10.3	10.5	10.8	10.4
5	10.4	10.9	10.2	11.0	10.6
Liming means	9.9	10.3	9.8	10.3	
6. J.I.P.2	15.9				

Least significant differences (P=0.05):

within table (including compost 6) .. .. ±0.7

between compost means 1-5 .. .. .. ±0.3

between liming means A-D .. .. .. ±0.3

Plants in JIP2 were far heavier than those in any of the sand-peat composts. Among the sand-peat composts, significant differences in mean plant weights followed exactly the same pattern as in Experiments 2 and 4, the weights increasing as the proportion of peat in the compost rose.

Liming treatments B and D were significantly better than A and C, but there was no consistent trend in relation to levels of application of lime. The interaction of liming treatments on composts, although significant, was also rather inconsistent. However, there does appear to be a trend towards heavier plant weights at the lower rates of lime application in the sandier composts, and at the higher rates in the composts containing more peat.

TABLE XIII

EXPERIMENT 5: *p*H AND *p*C VALUES

Compost	*p*H		*p*C		Compost	*p*H		*p*C	
	Initial	Final	Initial	Final		Initial	Final	Initial	Final
1A	6.10	7.38	3.05	3.71	4A	5.68	6.48	2.85	3.30
1B	6.29	7.58	3.11	3.61	4B	5.69	6.67	2.83	3.30
1C	6.54	7.35	3.12	3.67	4C	5.76	6.62	2.84	3.25
1D	6.56	7.51	3.13	3.73	4D	5.82	6.76	2.86	3.27
2A	5.98	7.24	3.01	3.63	5A	5.43	6.18	2.57	3.15
2B	6.09	7.41	3.04	3.58	5B	5.71	6.62	2.82	3.24
2C	6.35	7.29	3.08	3.55	5C	5.88	6.69	2.82	3.30
2D	6.39	7.42	3.07	3.64	5D	5.86	6.71	2.82	3.21
3A	5.76	7.05	2.89	3.55	6 JIP2	6.29	6.66	2.86	3.32
3B	5.80	7.22	2.92	3.52					
3C	6.00	7.21	2.92	3.54					
3D	6.11	7.24	2.95	3.40					

Discussion and conclusions

The percentage germination of antirrhinums and tomatoes in all the U.C.-type composts used in Experiments 1 and 2 was higher than in JIS, showing that these composts were at least as suitable as JIS for the purpose of germination. For antirrhinums the differences were not significant, but for tomatoes germination in the 1:1 and 1:3 sand:peat composts was significantly higher than in the 3:1 sand:peat compost or in JIS. For antirrhinums, though not for tomatoes, there was a consistent trend to higher percentage germination at higher liming levels.

In the one experiment with antirrhinums there were no significant differences between mean plant weights in any of the composts.

The results of the experiments with tomatoes also suggested that plants produced in some of the U.C.-type composts might be equal in weight to those in JI composts provided that the appropriate base fertiliser and liquid feeding were applied. In Experiment 2 there were no significant differences between mean plant weights in any U.C.-type compost and in JIS. In the pot-stage experiments, plants in U.C."C" compost in Experiment 3 did not differ significantly in weight from those in JIP1, and nutrition was obviously the factor limiting the growth of plants in sand-peat composts in Experiment 5, where JIP2 was significantly the best compost.

In experiment 4 as well as Experiment 5 inadequate nutrition limited plant growth in U.C.-type composts. The base fertilisers and liquid feeding recommended for U.C. composts (1) appeared adequate for tomatoes under the conditions of Experiments 2 and 3 in the early part of the year, but under conditions of greater intensity and duration of sunlight they appeared quite insufficient for satisfactory plant growth.

In all the factorial compost × liming experiments with tomatoes, mean weight per plant increased with an increasing proportion of peat in the compost, in most cases significantly. An exception to this relationship occurred in the relatively small Experiment 3, however, and the slight differences in base fertilisers and liming for the three U.C. composts (Table VII) were too small to explain the marked inferiority of the "D" compost in this particular trial. As the peat had been steamed for the U.C. and U.C.-type composts in all the experiments, it is possible that the chlorotic mottling which affected all plants in the "D" compost was due to manganese toxicity. Some support for this view may be gained from Experiment 5, in which the chlorotic mottling was most prevalent at high levels of peat and low levels of lime; time did not permit analytical examination of this matter, however.

The growth of plants in the Dempster-type composts in Experiments 3 and 4 was poor. The physical properties of the compost were very probably a major contributory cause.

In none of the experiments was there any consistent trend in plant weights in relation to rates of lime added to the composts. However, in both Experiments 2 and 4 mean plant weights in the 3:1 sand:peat compost were highest at the lowest liming level. Excessively high *p*H values in the sandier composts at the higher liming levels might therefore have contributed to the inferior growth of plants in them. The low *p*H values in some of the composts in Experiments 1 and 2 had no apparent effect on plant growth, although an effect on the germination of antirrhinums in Experiment 1 has already been referred to.

In conclusion, U.C.-type composts seem potentially as good as JI composts, both for the germination and seedling growth of antirrhinums and tomatoes and, under some conditions, for the pot stage in tomato propagation, as shown by experiments 1—3 during the winter period. However, growth in U.C.-type composts was not fully satisfactory during April and May, and the nutritional aspects of tomato propagation in these composts require further investigation.

Steam-sterilisation of the constituents of sand-peat composts is of questionable value. In the case of peat it may be harmful, and it seems probable that it was so in Experiments 3 and 5.

Dempster-type composts seemed to be physically unsuitable for tomato propagation in pots.

ACKNOWLEDGMENTS

The author's thanks are due to Dr. G. W. Winsor for his assistance and suggestions; and to the Ministry of Agriculture, Fisheries and Food for the post-graduate scholarship during the tenure of which this work was carried out.

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3. SOME HOST PLANT FACTORS AFFECTING FECUNDITY OF WHITE-FLIES

by

N. W. HUSSEY and BARBARA GURNEY

Introduction

Following his studies on population balance between Glasshouse White-Fly (*Trialeurodes vaporariorum* West.) and its parasite *Encarsia formosa* Gahan, Burnett (3) reported that, in natural populations, Aleyrodid fecundity is markedly influenced by changes in the physical environment and, particularly, by changes in the condition of the host plant leaves. He found that white-flies laid more eggs on young upper leaflets of tomato than on older ones which adults were no longer infesting (Burnett (2)). This preference had been suggested earlier by Milliron (10), who observed that adult white-fly populations constantly move from the lower, older leaves to the upper, more succulent leaflets of the host.

Kennedy and Booth (7) showed that the larviposition rate of *Aphis fabae* (Scop.) tended to be higher on growing and senescent leaves than on green mature leaves. This effect was correlated with the concentration of nitrogen in the phloem sap. A similar response to the concentration of leaf nitrogen was reported for *Macrosiphum pisi* (Kalt.) by Barber and Tauber (1).

A preference by white-flies for particular leaflets must be due to their superior attractiveness in colour or nutrient content. The tropisms governing the upward movement involved are probably a combination of negative geotropism (Fox-Wilson (4)) and a strong attraction to the colour of the apical leaflets. Moericke (11) demonstrated the attractive properties of yellow, and Lloyd (9) showed that adults preferred green and orange surfaces in proportion to the amount of yellow they contain.

The only information available on the effects of specific concentrations of nutrients in leaf sap on Aleyrodids is given by Joyce (6) and Haseman (5). Haseman grew plants on different nutrient solutions and demonstrated preferences by (i) permitting a large number of adults to disperse over the plants, and (ii) by caging a known number of adults on individual plants. The size of the populations at the end of the experiments were taken as the criteria for deducing any nutrient effects. He showed that *Trialeurodes* usually preferred plants of full nutrient status, but that phosphorus and magnesium deficient tomatoes were more attractive than normal. Joyce (6) found a high correlation between the density of the Aleyrodid *Bemisia tabaci* Gennad. on cotton and the concentration of leaf nitrogen.

To ensure the correct interpretation of future studies on population balance between white-fly and its parasite, more exact information on the effects of the host plant on the reproductive potential of white-fly is desirable.

Effect of ageing in both leaf and plant on fecundity

To confirm the restricted data available on the effect of leaf age, leaflets were removed, at weekly intervals, from similar leaves relative to successive trusses on six plants. The first leaflet was tested when it had grown to 2 in. in length. The leaflets were kept fresh in 3 in. x 1 in. tubes by dipping the petioles in vermiculite dampened with nutrient solution. Four female flies were enclosed on the leaflets for four days at a constant temperature of 75° F. in a glass-fronted incubator located in a room artificially lit for 16 hours a day. There was a marked decline in the oviposition rate as the leaflets aged (Table I).

TABLE I

MEAN FECUNDITY OF WHITE-FLIES ON LEAFLETS OF DIFFERENT AGES
(Eggs/female/day)

Age of leaflet	Truss							
	1	2	3	4	5	6	7	8
First 2 in. leaflet below truss	7.9	2.7	5.7	10.3	8.0	8.0	2.1	4.5
Leaflet one week older	—	5.0	5.7	7.2	1.1	1.0	2.1	3.9
Leaflet two weeks older	5.2	2.8	0.8	1.8	0.8	2.5	0.8	1.7

Senescence could also influence the white-flies by altering the metabolism of the plant as it grows older, and this was tested by continuing to remove 2 in. leaflets from below successive trusses on three plants between September 1959 and June 1960. No decrease in fecundity occurred over the twenty six trusses tested, apart from a seasonal decline over the winter solstice. This retardation of oviposition must have been due to low light intensity or to its short duration rather than low temperature, as the minimum temperature of the growing house was thermostatically controlled at 65° F. The effect was further demonstrated by testing leaflets from below the first four trusses on a succession of plants grown at monthly intervals over the same period (Table II).

TABLE II

FECUNDITY OF WHITE-FLIES ON A SUCCESSION OF YOUNG PLANTS
(Eggs/female/day)

Leaf	Dates during which tests made					
	9/10-10/11	24/11-6/1	19/2-23/3	19/3-17/4	13/4-11/5	8/5-1/6
1st leaf below truss 1	8.4	1.4	3.8	7.8	6.9	6.8
1st leaf below truss 2	5.4	2.8	6.5	7.2	5.6	5.9
1st leaf below truss 3	5.1	3.8	5.6	4.6	9.4	6.0
1st leaf below truss 4	6.4	4.4	8.2	6.8	6.9	5.4

Effect of light intensity and duration on oviposition

The apparent correlation between low light intensity and low egg production was studied in the laboratory by exposing the culture tubes described above at different distances from a number of lights of different intensity, but the results showed no consistent pattern. Another experiment was conducted by exposing the culture tubes to different diurnal periods of light at constant temperature (Table 3). Again there was no significant effect, and one must conclude that the reduction on the growing plant was due to a change in the products of metabolism in the host under these conditions.

TABLE III

FECUNDITY UNDER DIFFERENT DURATIONS OF LIGHT

Duration of light (hours)	Eggs/female/day
0	5.3
4	5.3
8	5.1
16	6.2
20	5.3

Observations on choice of feeding site by white-flies

In a series of observations adult white-flies were enclosed within 2 in. plastic pill-boxes covered completely with black paper, apart from two $\frac{1}{2}$ in. discs punched in the lid and covered with pieces of leaf tissue. One of these portions of leaf was several weeks older than the other.

About twenty adult flies were placed in the box, which was maintained in bright sunlight, artificial light or complete darkness for each twenty-minute test. Whatever the conditions all the adults settled on the younger leaf after twenty minutes, although some may have settled on the older tissue at first. When a similar series of observations was made with the plastic lid intact so that the adults were unable to probe the leaf-tissues, the flies remained scattered throughout the whole experimental period and at no time congregated below the leaf discs.

These observations suggest that although adults may be attracted to suitable leaflets by a combination of tropisms, the final selection of the resting site is nutritional following feeding probes.

Effect of host nutrition on white-fly fecundity

Preliminary studies on the effect of host nutrition were made by detaching leaflets from tomatoes grown in aerated nutrient solutions developed by Le Roux (8). These leaflets were incubated as usual at 75° F. and the fecundity of four females per leaflet measured over four days.

These early observations were made on plants grown with different levels of nutrient nitrogen, but although the concentration was varied between 105 and 434 p.p.m. no significant differences were detectable in rates of oviposition. Similar tests on plants grown on different concentrations of phosphorus did suggest a positive effect (Table IV), but there remained some doubt as to whether measurements of oviposition rates over limited periods were valid indices of nutrient effects. The method could not detect changes in total fecundity, nor could it distinguish whether any effect had operated through the adult or immature stages.

TABLE IV

WHITE-FLY FECUNDITY ON LEAFLETS FROM PLANTS GROWN WITH DIFFERENT LEVELS OF PHOSPHORUS

Concentration phosphorus	Mean oviposition of 40 adults
p.p.m.	*Eggs/female/day*
210	8.7
238	7.5
252	10.9

Another technique was used to establish these points. Plants were grown in three different nutrient solutions (P0, P1 and P3) and white-fly adults reared from eggs laid on these plants were collected for oviposition tests. These adults were enclosed within gelatin capsules (size 00), placed on a further series of plants grown on similar nutrients, by cutting out tongues of leaf-tissue to fit within the capsules and blocking the open end with cotton-wool. The flies were changed to new leaves once a week and the number of eggs laid throughout life recorded. Twenty flies were reared on the same nutrient level at which they had developed from the egg, and ten more were transferred for oviposition to plants of different nutrient status.

Phosphorous deficiency decreased both oviposition rate and total fecundity (Table V), but there was no significant difference between the performance of flies on P1 and P3 plants.

TABLE V

FECUNDITY ON PLANTS GROWN WITH DIFFERENT LEVELS OF PHOSPHORUS (±S.E.)

Nutrient status of plants used for oviposition tests	P0		P1	P3	
Concentration of phosphorus (*p.p.m.*)	0		210	252	
Nutrient status of ovipositing females	P0	P3	P1	P3	P0
Eggs/female/day	8.8±1.5	10.6± 0.1	31.2± 6.0	25.4± 3.1	25.3±2.4
Total fecundity/female	43.6±6.6	59.8±12.2	199.8±19.2	219.6±15.7	184 ±33

In the transfer experiments the fecundity of the transferred flies was approximately the same as that of flies tested at the same nutrient level at which they had been reared. The effect of the nutrient status of the host plant therefore operated through the adult whilst feeding during the oviposition period.

Conclusions

Adult white-flies reach their feeding site on the apical leaflets of their host plant by a combination of negative geotropism and attraction to yellow-green colour. Once alighted they remain settled if probing provides a suitable nutrient content in the sap. The host plant may affect white-fly fecundity through the nutrient content of the sap, which can alter under different fertiliser treatments, in senescing leaflets or in plants growing in poor light. Haseman (5) claimed that white-flies preferred phosphorus deficient tomatoes to those on normal nutrients. This conclusion is not consistent with our results but, by his technique, the flies could have been reacting to the colour of chlorotic plants rather than to nutrients.

Studies on white-fly/parasite population dynamics can only be correctly interpreted if variations in the reproductive potential of *Trialeurodes* can be eliminated. Our results suggest that experiments with white-flies may be done on plants of any age throughout the year except between November and February. Only phosphorus and nitrogen have been studied so far, and reproduction seems to be little affected by quite large differences in host nutrition. Studies on oviposition rate by adult white-flies over a few days is a suitable technique for investigating the effects of other essential nutrients.

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4. AMERICAN STUNT VIRUS IN ENGLISH CHRYSANTHEMUM STOCKS

by **M. HOLLINGS**

Stunt virus was isolated from English chrysanthemum varieties at Harpenden in 1952, but until recently occurred rarely and affected only occasional plants on a few nurseries. The disease did not appear to spread on nurseries, nor could spread be demonstrated experimentally by leaf or root contact between infected and healthy chrysanthemums, and spread by cutting knife was slight. Infected plants could be "cured" by heat treatment, and the disease presented no problem. Later, another isolate of "English stunt", obtained from the variety 'Penrod', was not eliminated by heat treatment.

In recent years the increased popularity of American chrysanthemum varieties, especially some of the spray types, has resulted in an appreciable number of stunt-infected plants being introduced; stunt has been confirmed in varieties 'Beauregard', 'Chocod', 'Corsair', 'Ginger', 'Minstrel', 'Paramount', 'Pippin', 'Portrait' and others, and more recently in 'American Beauty' and 'Yellow Fred Shoesmith'. This "American stunt" virus was not eliminated by heat treatment, and was much more readily spread by cutting knife and handling plants than the "English stunt" isolates previously tested. In preliminary experiments, however, less spread occurred when the cutting knife was frequently dipped in 3% tri-sodium phosphate solution during use.

Stunt virus is a real danger to the chrysanthemum industry, and it is essential that infected plants should be recognised and destroyed. Although several viruses can dwarf chrysanthemums, stunt virus disease has three diagnostic features: (i) the whole plant is about one-half or two-thirds the normal size, with the leaves and internodes proportionally smaller—the plant does not appear deformed, merely reduced in scale, (ii) flowers on affected plants open up to two weeks earlier and (iii) are smaller than normal. Early flowering is an important and conspicuous symptom which greatly helps recognition of affected plants in a bed, and distinguishes plants infected with stunt from those that are abnormally small for other reasons. There are often other flower symptoms: red, pink and bronze blooms may be bleached, though they do not show the streaking or "colour breaking" typical of aspermy infection. The flowers of most varieties are obviously inferior, though actual distortion is rare.

American stunt virus retained infectivity when precipitated from clarified chrysanthemum sap by ammonium sulphate; but an antiserum made from such preparations did not react with infective sap. An antiserum made by injecting ultracentrifuged preparations into rabbits reacted specifically with stunt virus in chrysanthemum sap in gel diffusion slide tests only under certain conditions. Unspecific precipitates caused by constituents of both normal and infected chrysanthemum sap frequently overshadowed the specific reaction, and the test cannot yet be used for indexing chrysanthemums (see Plate I).

Because grafting tests for stunt require 2-10 months before the results are known, a serological test, giving a result in as many hours, would be of great practical value, and work continues to devise one. The standard test for stunt virus is to graft scions from the suspect plant to the chrysanthemum variety 'Mistletoe'; if stunt virus is present, small yellowish spots and flecks appear on the younger leaves of the 'Mistletoe' plant after 2-10 months, and the leaves subsequently produced are about half the normal size (see Plate II). Symptoms often develop in 3-4 months, but some tests, especially those done in late summer or autumn, take much longer. American workers have reported that symptoms take only two months to appear, but under our conditions this time limit would not give a reliable answer.

Only a very few plants in the family Compositae have so far proved susceptible to stunt virus, so that for practical purposes infected chrysanthemums are the only likely source of infection. There is no evidence that stunt can be transmitted by any of the insects tested (including aphids), and the only known means of spread is by handling plants.

PLATE I. Serological gel diffusion test. Antiserum to chrysanthemum stunt virus is placed in the central well, crude sap from healthy chrysanthemum leaves in the well on the left (H), and from stunt-infected leaves in the well on the right (ST).

PLATE II. Leaves of chrysanthemum variety 'Mistletoe': from healthy plant (left) and showing diagnostic symptoms of stunt (right).

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5. INVESTIGATIONS ON SOIL STERILISATION: PRELIMINARY RESULTS OF A COMPARISON BETWEEN METHAM-SODIUM, STEAM AND CHLOROPICRIN

by

W. H. READ

In view of the interest in certain recently introduced soil sterilising products containing metham-sodium (sodium methyldithiocarbamate), the results of the first year's experiments in which this compound was compared with steam and chloropicrin, are recorded. This comparison is part of a detailed investigation of problems connected with the use of chemical soil sterilising agents, and in particular those arising from the use of metham-sodium.

The comparisons were made in two 100 ft. x 14 ft. glasshouses in which the growth of the plants in 1958 indicated that sterilisation of the soil was required in order to maintain fertility. The roots of the plants removed from the houses at the end of the 1958 season were examined in the Plant Pathology Division, and it was reported that although they showed considerable lack of uniformity, their general condition throughout the two glasshouses was very poor, the smaller roots having rotted away and the larger roots being very "corky".

Colletotrichum atramentarium was fairly evenly distributed on plants in one glasshouse, but was not as abundant as is normally expected on plants at the end of the season when grown in an unsterilised soil. In the second glasshouse *Colletotrichum* was not evident. There was no loss of plants in 1958 through attack by other soil fungi such as *Verticillium* spp., *Phytophthora* spp. or *Didymella lycopersici*, nor were root-knot eelworm (*Meloidogyne* sp.) or potato root eelworm (*Heterodera rostochiensis*) present.

The insect fauna was examined by the Entomology Department both before and after the sterilisation treatments. No previous data exist on the numbers of the various groups of insects which can be regarded as normally occuring in glasshouse soils, but the types of fauna found were what might be expected.

The borders had not been sterilised since the erection of the glasshouses in 1954, and so the soil could be considered a typical soil requiring "sterilisation" treatment to restore fertility rather than treatment primarily designed to destroy fungi or insects.

Experimental

The three sterilisation treatments and an unsterilised control were replicated four times in plots 21 ft. x 5 ft. in a Latin square layout. At both ends of the houses two guard rows of tomatoes were grown to minimise "end of house" effects. The plots were separated from one another by inserting polythene sheets to a depth of two feet and attaching these to boards a few inches below the surface of the soil.

After removing the 1958 crop and forking out the roots, the houses were dug and composted straw worked in at the rate of 30 tons/acre, the soil being brought to the fine tilth desirable for chemical sterilisation.

Treatments

(*a*) *Steaming*

Date of steaming, 3rd November, 1958.

The "Hoddesdon-pipe" system (1) was used, with the pipes at a depth of 12 in. and 15 in. apart. Steam was passed sufficiently long to reach and maintain a temperature throughout the soil of 210° F. for 20 minutes.

(*b*) *Metham-sodium*

Date of application, 13th November, 1958.

A proprietary solution containing (on analysis) 49.78% w/v. of sodium methyldithiocarbamate dihydrate was diluted × 200 (1 pint in 25 gallons) and applied as uniformly as possible at 4½ gal./square yard. Light waterings, sufficient to wet the surface soil to a depth of ¼ in., were given two days and seven days after drenching the plots with the metham-sodium solution.

(*c*) *Chloropicrin*

Date of application, 12th November, 1958.

Chloropicrin was injected at 3.5 ml. per injection at 12 in. staggered spacings, and at a depth of 6 in. This dosage is equivalent to 400 lb./acre. The standard procedure of closing the injection holes in the soil with the heel, consolidating the surface by treading, and sealing by a light watering was adopted. Additional light "sealing" waterings were given after two and seven days.

(*d*) *Controls*

The four control plots were undisturbed in the period between the first digging and flooding.

Post-sterilisation treatments

Three weeks after application the plots treated with chemicals were forked over, leaving the surface as rough as possible, to hasten the release from the soil of chloropicrin and the volatile products derived from the metham-sodium. This operation was repeated after a further two weeks. All the borders were "flooded" eight weeks after the chemical sterilising treatments were given.

Plots which were steamed received base dressings of 3 oz./sq. yd. of hoof and horn and 6 oz./sq. yd. of sulphate of potash; those treated with metham-sodium and chloropicrin were given 4 oz./sq. yd. of hoof and horn and 5 oz./sq. yd. of sulphate of potash, and the control plots 6 oz./sq. yd. of hoof and horn and 4 oz. of sulphate of potash. These differences were considered desirable in view of the expected variations in the amounts of available nitrogen resulting from the treatments. All plots received 4 oz./sq. yd. of superphosphate as analyses had shown the soil to be of low phosphate status.

The plots were planted on March 6th-7th and, as it was necessary to grow a number of tomato varieties for other experiments, each plot was planted with two rows of the following varieties: 'Potentate', 'Ailsa Craig', 'Moneymaker', 'E.S.5', 'L.M.R.1' and 'Delicious'. Normal cultural treatment was given, and the fruit from each variety in each plot weighed and graded separately.

The disadvantage of combining the cultivation of six varieties with the experiments on soil sterilisation was the necessity to stop the plants when they reached the supporting wires, with consequent reduction in crop.

Results

No adverse effect from either soil sterilising chemical was observed.

The overall yields for the six varieties combined were as follows:

Steam	9.75 lb./plant
Metham-sodium	9.48 lb./plant
Chloropicrin	9.63 lb./plant
Control	7.25 lb./plant
Significant difference (P=.05)	=0.44 lb./plant

The detailed statistical examination of the data to provide information on the responses of the different varieties, including information on fruit quality, is not yet available.

Discussion

The results show that under the conditions of this experiment there was no significant difference between the yields from plots sterilised by steam, chloropicrin or metham-sodium. All sterilisation treatments gave very significant increases over the unsterilised plots.

As already mentioned the statistical examination of the effects of the sterilisation methods on individual varieties and on fruit quality is not yet complete.

It must not be overlooked that these results have been obtained as the result of a single trial under one set of conditions where serious soil diseases and pests were not the factors responsible for poor growth. Nevertheless it appears that metham-sodium can, under some conditions, restore the fertility of a soil to about the same extent as steaming or treatment with chloropicrin.

In this trial a period of sixteen weeks elapsed between treating the soil and planting out tomatoes, and the soil was forked over twice in this interval. Lettuce plants placed in the borders as test plants seven weeks after treatment with metham-sodium and chloropicrin (the vapour of which is highly injurious to plants) were uninjured, but it is not yet known whether such test plants can be regarded as entirely reliable indicators of the absence of substances which may injure tomatoes or other crop plants. The distribution of metham-sodium and its decomposition products in treated soils is under examination, and a note on the chemical determination of these in soils is published elsewhere in this Report (page 108).

There was no evidence that tomato mosaic virus, which may under certain conditions infect plants via the soil, was destroyed by any of the sterilising methods as it proved impossible to differentiate between infection via the soil and infection arising as a result of handling the plants.

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6. PRELIMINARY OBSERVATIONS ON THE CONVERSION OF SODIUM N-METHYLDITHIOCARBAMATE (METHAM-SODIUM) TO METHYL ISOTHIOCYANATE IN SOIL

by

J. T. HUGHES

In dilute aqueous solution sodium N-methyldithiocarbamate, for which the common name metham-sodium has been proposed, may be readily converted to methyl *iso*thiocyanate, and it has been assumed that this compound is responsible for the soil-sterilising properties of metham-sodium solutions applied to the soil as drenches or by injection (2). Evidence has been published for the occurrence of a parallel transformation (into di*iso*thiocyanates) to account for the *in vitro* fungicidal activity of ethylenebisdithiocarbamates (1, 3), but no evidence for the conversion of sodium N-methyldithiocarbamate into methyl *iso*thiocyanate in the soil has been found in the literature.

Experiments outlined below show that methyl *iso*thiocyanate is formed rapidly from metham-sodium in the presence of a soil, even at low temperatures, at the concentration used in field applications. The high rate of conversion appears to be mainly due to the direct action of the soil particles, as the aqueous extract of the same soil causes only a very slow transformation, comparable with that which occurs in distilled water solutions of the same concentration.

Experimental

Known amounts of an approximately 0.2% solution of metham-sodium (recrystallised as the dihydrate from a commercial solution) were added to standard weighed amounts of an air-dried unsterilised loam (pH = 7.6, moisture holding capacity = 28.7% dry weight). Some of the treated samples of soil were kept at 5° C. and others at 25° C. as were an equal number of control samples of untreated soil and distilled water. All were kept in glass-stoppered flasks.

At selected time intervals samples were extracted by shaking vigorously with a known volume of water; the extracts were centrifuged, aliquots of the clarified liquid were diluted quantitatively and their absorption spectra determined, using a corresponding solution from the untreated soil as a blank (Figure 1A). Equal aliquots were treated with ammonia solution to convert any methyl *iso*thiocyanate present to N-methylthiourea, and after standing for 30 minutes and diluting as before, their absorption spectra were also recorded, this time using a corresponding ammonia treated solution from the untreated soil as a blank.

The spectra obtained from the ammonia treated extracts (not shown) are due to the combined absorption of methylthiourea and residual unchanged metham. The absorbance values obtained at each wave-length for residual metham (Figure 1A) have been subtracted from these combined values and the nett absorbances plotted against wavelength (Figure 1B). These spectra, although showing some anomalous negative values (apparently due to continued decomposition of metham after treatment of the extracts with ammonia), are typical of methylthiourea in the region of 235mμ (λ max.), and demonstrate the progressive formation of methyl *iso*thiocyanate.

The amounts of unchanged metham-sodium and of methyl *iso*thiocyanate were estimated (Table I) by reference to calibration curves obtained by similar measurements at selected wave-lengths on known mixtures of the two compounds (Figure 2).

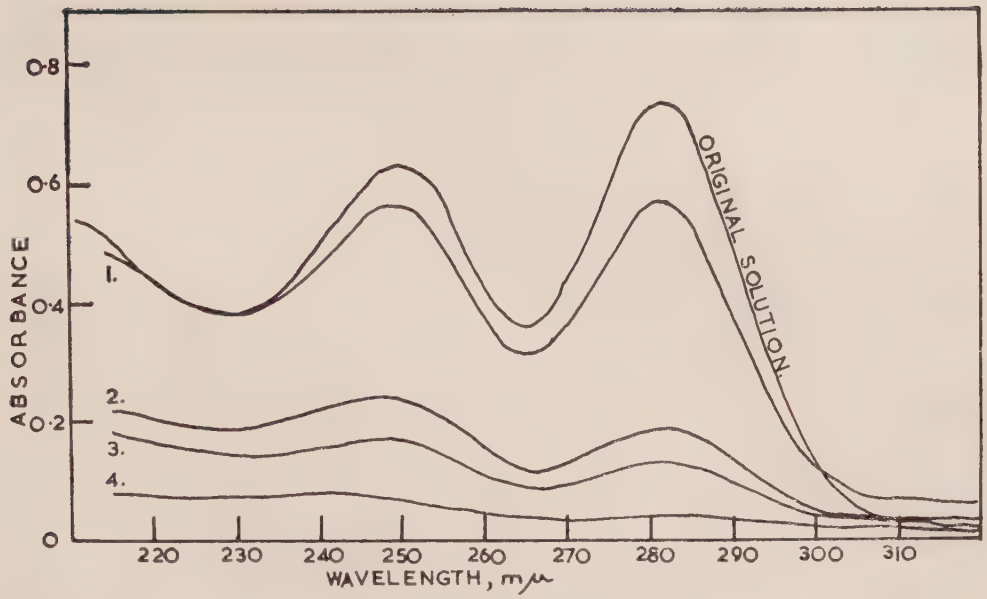

FIGURE 1A. Absorption spectra of extracts from soil treated with metham sodium:
(1) Extracted immediately
(2) After 5 minutes at 25°C
(3) After 15 minutes at 25°C
(4) After 45 minutes at 25°C

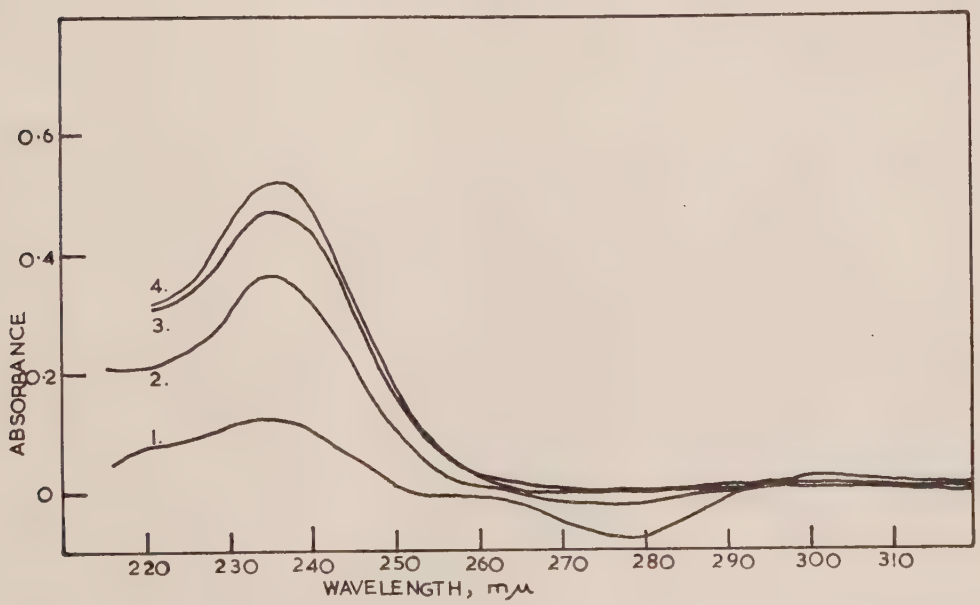

FIGURE 1B. Absorption spectra of the extracts (FIGURE 1A) after treatment with ammonia and correction for unchanged metham sodium present.

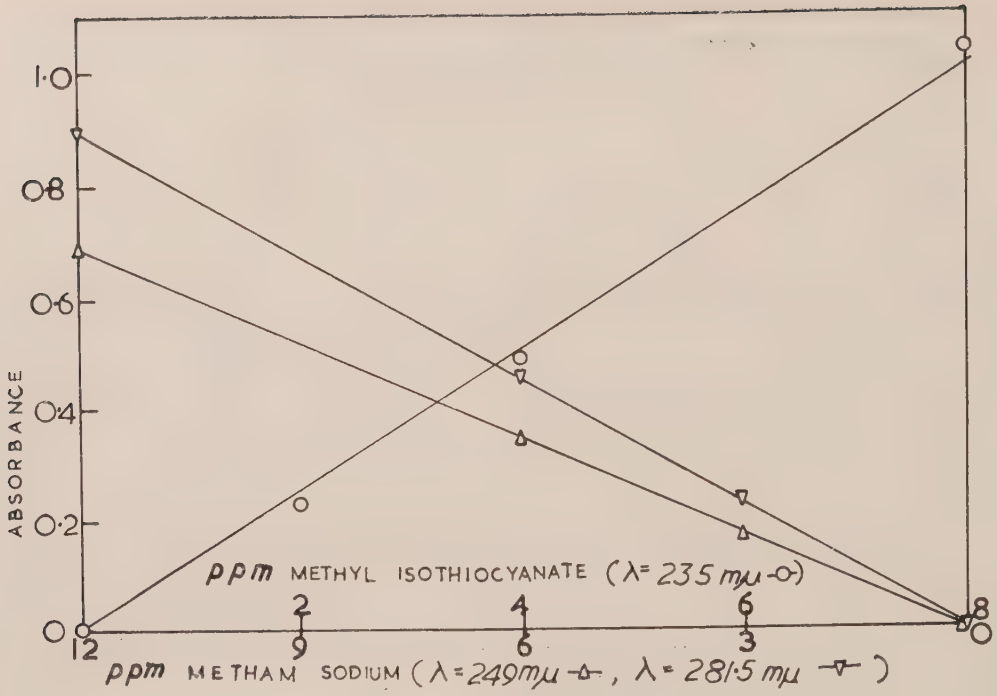

FIGURE 2. Calibration curves obtained by absorbance measurements on solutions of mixtures of metham sodium and methyl *iso*thiocyanate.

TABLE I

CONVERSION OF SODIUM METHYLDITHIOCARBAMATE (METHAM-SODIUM) TO METHYL ISOTHIOCYANATE IN SOIL: AMOUNTS OF THE TWO COMPOUNDS RECOVERED FROM TREATED SOIL AFTER STATED PERIODS AT 5°C AND 25°C (AS % W/V OF THE SOIL SOLUTION)

Temperature	Period before extraction	Metham-sodium	Methyl-*iso*thiocyanate
(°C)	(*minutes*)	(% *w/v*)	(% *w/v*)
–	–	.208	–
25	0	.174	.020
,,	5	.068	.060
,,	15	.048	.078
,,	45	.018	.086
5	30	.080	.058
,,	60	.052	.070

In further experiments an approximately 1% solution of metham-sodium in distilled water was diluted five times to give 0.2% solutions in distilled water and in an aqueous extract of the loam. These solutions were kept at 25° C. and the metham-sodium and methyl *iso*thiocyanate present were estimated spectrophotometrically initially and at intervals (Table II).

TABLE II

CONVERSION OF METHAM-SODIUM TO METHYL ISOTHIOCYANATE IN WATER AND AN AQUEOUS SOIL EXTRACT ISOLATED FROM SOIL (AS % W/V OF THE SOLUTION OR EXTRACT)

Period at 25°C	Metham-sodium		Methyl *iso*thiocyanate	
	Distilled water	Loam extract	Distilled water	Loam extract
(*Hours*)	(% *w/v*)	(% *w/v*)	(% *w/v*)	(% *w/v*)
0	.220	.224	.007	.007
3	.214	.208	.013	–
5	–	–	–	.008
24	.206	.180	.008	.015

Discussion of results

Table I shows the amount of sodium methyldithiocarbamate extracted after different intervals from soil treated with a solution of the metham-sodium. From these results it is seen that the dithiocarbamate is very rapidly converted to methyl *iso*thiocyanate (0.09% of methyl *iso*thiocyanate is equivalent to 0.2% of metham-sodium).

The decomposition in this soil appeared to result from the presence of the soil solids, and to be little influenced by the aqueous soil extract, as the extent of conversion of the dithiocarbamate to the *iso*thiocyanate in the soil extract was small after 24 hours and not appreciably greater than that in distilled water.

Further investigations on the decomposition of metham under different conditions and in different soils are being undertaken, and these results, together with a fuller account of the analytical methods, will be published in due course.

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7. STUDIES ON THE PREVENTION OF BASAL ATTACKS OF TOMATO STEM ROT (DIDYMELLA LYCOPERSICI) WITH CAPTAN

by

W. H. READ

The watering of the bases of the stems of tomato plants and the soil in their immediate vicinity with captan (N-trichloromethylthio-*cyclo*hex-4-ene-1:2-dicarboxymide) was shown in experiments made in 1958 (3) to greatly reduce the number of plants attacked by *Didymella lycopersici* when planted into soil infected with this fungus. The 1958 results suggested that better control might be obtained when the first application was made to the plants in pots within a day or two of planting, rather than when the first application was made a day or two after planting.

The experiments made in 1959 were designed to obtain more information as to whether the pre-planting treatment was superior to the post-planting treatment, and to see if the amount of captan could be reduced without loss of effectiveness, as the growth of tomatoes was slightly checked by the first treatments applied in 1958.

It was also observed in 1958 that slight scorching of the extreme tips of the lobes of the leaflets occurred at the points where guttation was most pronounced. Such scorching is frequently observed with certain systemic insecticides (e.g., schradan and dimefox), and the possibility that protection was conferred by the systemic action of captan, or other products in a proprietary formulation of captan, was investigated.

Experimental

Prevention of infection

The borders of the glasshouse were steamed after digging in composted straw at a rate equivalent to 40 tons per acre, flooded and inoculated with *Didymella lycopersici*, ten days before planting the tomatoes, by incorporating a sand-oatmeal culture of this fungus as uniformly as possible into the soil to a depth of about three inches.

Three replicates of each of the following treatments were randomised in the glasshouse, and there were also three control plots in which the plants were not treated with the fungicide.

(*i*) First application to plants in pots one day before planting—3 fl. oz. of 0.25% captan per plant. Second application 25 days after planting—5 fl. oz. of 0.25% captan per plant.

(*ii*) First application one day after planting—4 fl. oz. of 0.25% captan per plant. Second application 25 days after planting—5 fl. oz. of 0.25% captan per plant.

(*iii*) First application one day after planting—4 fl. oz. of 0.5% captan per plant. Second application 25 days after planting—5 fl. oz. of 0.5% captan per plant.

The lower four inches of the stems of the plants were wetted at the first application, and about six inches at the second application. The drenches were applied to an area of soil within a radius of about three inches from the base of the stem at the first application to the planted-out plants in treatments (*ii*) and (*iii*), and to a radius of about six inches at the second application.

Plants which wilted were removed and their roots examined to confirm that they were infected with *Didymella*.

The mean percentages of plants infected with *Didymella* are recorded graphically (Figure 1).

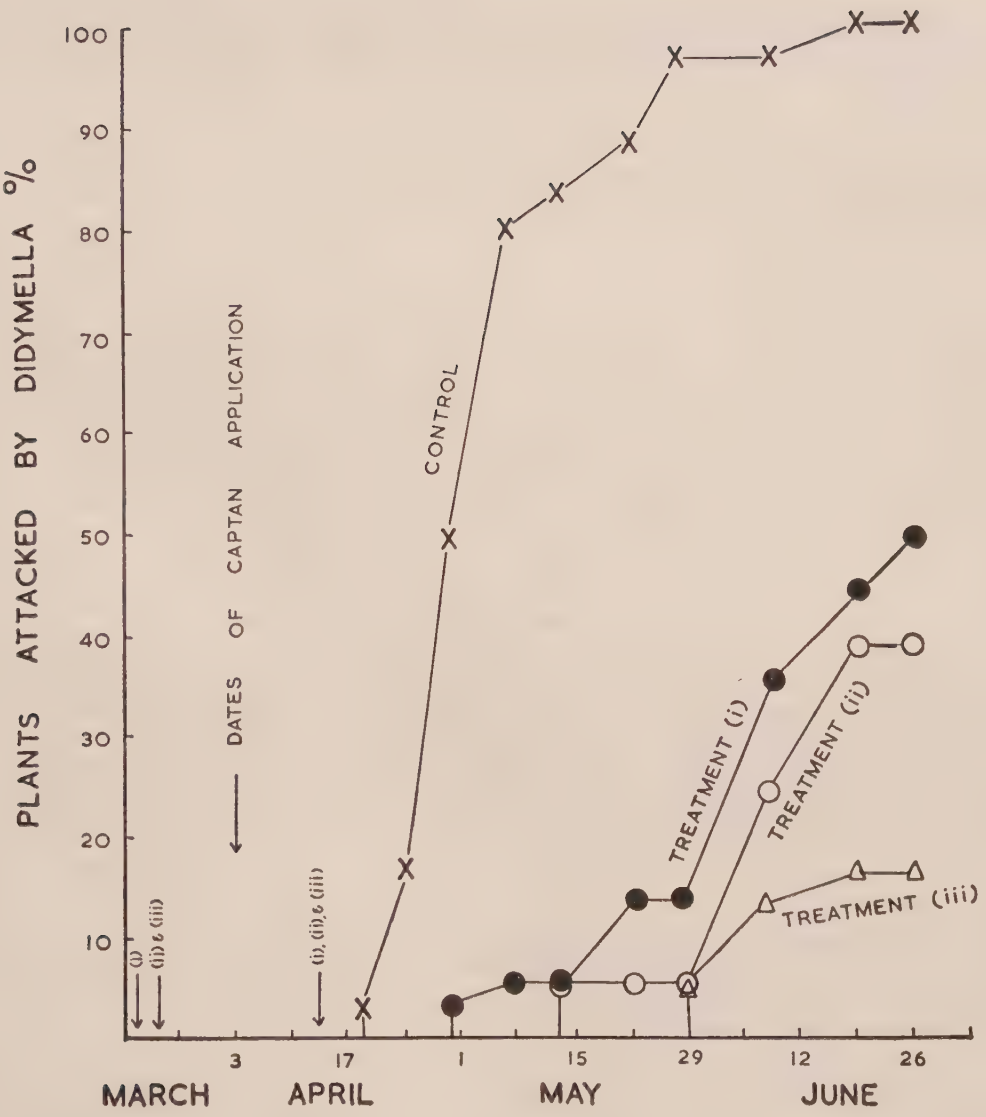

FIGURE 1. Prevention of basal attacks of *Didymella* Stem Rot with captan.

Damage to plants

The scorching of the apical tips of the leaflets of the plants following the first application of captan, noticed in 1958, again occurred, and there appeared to be a slight temporary check to growth where the first application was to the plants in pots. The phytotoxicities of captan and of a proprietary, dispersible powder formulation containing 50% of technical captan, were therefore examined.

Tomato plants about six inches in height and with six leaves exceeding two inches in length were treated by watering the soil with a suspension of purified captan (m.p.173°-174°) in water, and other similar plants with the equivalent amount of a formulated product containing 50% of technical captan.

The results in the table show that the check to growth from the proprietary formulation was considerably greater than that caused by the purified captan.

TABLE

EFFECT OF CAPTAN, IN PURIFIED FORM OR AS A COMMERCIAL FORMULATION, ON GROWTH OF TOMATO PLANTS

Captan (*mg/g air dried soil*)	Mean fresh weight of plants (g) 20 days after treatment	
	Purified captan	Commercial formulation
1.6	15.0	8.8
0.8	21.8	7.6
0.4	20.1	16.3
0.16	20.5	19.3
nil	20.6	20.4

Although the purified captan suspended in water caused little check to growth at the highest rate, which is equivalent to 6 fl. oz. of 0.25% captan to a 3 in. pot, it caused as much scorching of the tips of the lobes of the leaflets as the formulated captan. The latter contains considerable amounts of dispersing agents, and it has not been determined whether it is these dispersing materials, or impurities in technical captan, which are responsible for the greater injury caused by the proprietary formulated product.

Possible systemic action

In view of the similarity between the effect of soil applications of captan to plants and that of known systemic compounds, the possibility that captan conferred protective resistance against infection by *Didymella* was investigated by inoculating the stems of tomato plants, grown in captan-treated soil, with *Didymella* spores.

In these experiments it was not possible to infect more than a small percentage of unwounded stems of either treated or untreated tomatoes with *Didymella* by spraying the plants with a spore suspension. There was no indication that the stems of plants grown in soil containing captan were less readily infected than those grown in untreated soil.

Stems slightly abraded were readily infected by spraying with a spore suspension, and no evidence was found that purified captan or commercially formulated technical captan had any systemic, protective action.

Discussion

The results obtained in 1959 confirm that captan has a very marked effect in reducing attacks by *Didymella* when applied to the lower portion of the stem and surrounding soil of tomatoes planted in an infected soil. This protection does not appear to be due to captan acting systemically, although the type of damage caused by purified captan to tomatoes following its application to the

soil suggests that some systemic compound is absorbed by the plants. In this connection it is interesting to note that Napier *et al.* (2) found captan acted systemically against *Botrytis fabae* on broad beans, but work by Fawcett *et al.* (1) showed it did not confer appreciable resistance to infection of tomatoes by *Alternaria solani* through systemic action.

In this year's experiments treatment of the plants after planting, with 4 fl. oz. of 0.25% captan, gave results equal to or better than treatment of the plants whilst in pots with 3 fl. oz. of 0.25% captan. Treatment with 4 fl. oz. of 0.5% captan immediately after planting, followed by an application of 5 fl. oz. of 0.5% captan, gave better results than equal volumes of 0.25% captan.

A feature of the glasshouse trial was the very high incidence of infection, and it is probable that the incorporation of composted straw before steaming provided a very favourable medium for the fungus. None of the treatments gave complete control under the severe conditions of this test. Treatment of plants whilst in pots with 3 fl. oz. of 0.25% purified captan caused a very slight check to their growth, and commercial captan formulated as a dispersible powder was more injurious; consequently post-planting application appears preferable. Large scale trials on a wide range of soil types and under different cultural conditions are necessary, however, before the use of captan drenches to control *Didymella* can be proved quite safe.

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8. A REVIEW OF THE LITERATURE ON PLANT CONTAINERS AND MOULDED BLOCKS WITH SPECIAL REFERENCE TO THE POROSITY OF POTS

by

A. C. BUNT

Several types of container and moulded block are used by growers for the raising of plants which are either to flower and mature within the container, e.g., cyclamen, or those which are ultimately to be planted into glasshouse beds or the field, e.g., tomatoes and cauliflowers.

By tradition the porous clay pot has been the most widely used container. More recently interest has been shown in alternative containers, because of economic advantages, better growth or easier management. The alternatives most widely used are pots made from peat, paper, wood pulp or similar materials, peat blocks (units of compressed peat) and soil blocks (units of compressed compost). The recent development of the plastics industry has led to the introduction of various plastic containers, e.g., polythene, polystyrene, etc.

For the purpose of this review, which was undertaken as a prelude to a study of plant containers at the Institute, it is convenient to examine firstly the effect of the porosity of the container, from physical, chemical and plant growth points of view, and secondly the various alternatives to the clay pot.

Porous clay pots

Physical aspects of porosity

Critical examination of certain physical aspects of the porosity of the pot has been made by Jones (16, 17, 18), Hubbell (12, 13), Decker (4), Breschke (2), Knight (20), at the Institute of Horticultural Engineering, Wageningen (15), and by Eastoe and Pollard (7). The apparent porosity of a clay pot is the ratio of the volume of the open pores to the bulk volume of clay, and is usually expressed as a percentage. There is no standard porosity for the clay pot, but values of 38 per cent have been reported by the British Ceramic Research Association (3), and 42 per cent by Lawrence (23). Breschke (2) found the apparent porosity of pots from five sources in Germany to vary from 18.3 to 31.1 per cent, depending on the mould and firing temperature. The tensile strength of the pots varied with source and size, but was not correlated with the porosity. Eastoe and Pollard (7) reported a porosity range of 28 to 39 per cent for five types of British-made pots.

Jones (16) examined the effect of the structure of the pot on the soil temperature. In a glasshouse with an ambient temperature of 88° F. the temperature of the soil at 12.30 p.m. in the centre of a clay pot was 85° F. and in a non-porous (glass) container 105° F. This difference in temperature between the porous and the non-porous containers was attributed to the cooling effect of the evaporation of water from the wall of the porous pot. In another experiment Jones (17) reported the mean loss of water from a 3 in. porous container to be 32.5 g., and from a non-porous container 12.4 g., during the period 9 a.m. to 2.30 p.m., the soil temperatures within the containers at 2.30 p.m. being 79° F. and 100° F. respectively. The difference in soil temperature due to the porosity of the container reported by this worker is much higher than the 3° F. found by Decker (4) or the 2° F. found by Hubbell (12).

The nett water loss from porous containers is influenced by both the total porosity and the pore sizes within the pot wall, and also by the nature of the bench surface. Eastoe and Pollard (7) determined the water permeability of five types of pots by measuring the daily loss in weight when the pots were filled with water and the tops sealed with tin foil. The relative evaporating capacity

was taken as the average loss of water through the pot wall expressed as a percentage of that loss from a free water surface of the same area as the pot wall. Values of 4.4 to 78 per cent were obtained.

Jones (18) compared the rate of water loss from 5 in. porous pots placed on a moist bench surface consisting of soft coal cinders, with that from similar pots stood on a dry wood surface. The daily loss in water varied with the prevailing weather conditions, the mean loss from pots on the dry surface being 48.7 g. per day and from those on the moist bench surface 19.2 g. per day. The difference between these values can be attributed to (*a*) the absorption of water by the capillary action of the pot from the moist bench surface and (*b*) the increased relative humidity around the pots stood on the moist soft coal cinders.

When geraniums in 4 in. pots were first allowed to dry out and then given 100 g. of water, the weight of water absorbed by the pot in the subsequent 1½ hours was 22.6 g., and the loss of water due to evaporation and transpiration in this period was 6.2 g. Jones (18) estimated that 40 per cent of the amount of water applied daily to 3 in. and 4 in. pots was absorbed by the pot and 60 per cent was available for the soil and the plant. It was concluded from the use of a rubber vacuum disc that the word "porous", as applied to moist flower pots, should be limited to mean porosity to moisture. Air does not pass through the wall of a moist flower pot.

Following this work Jones and Haskins (19) reported that plants in non-porous containers required about half the quantity of water of plants in porous containers. A similar value was given by Hunter (14) for the first 28 days' growth of tomatoes. After 56 days plants in the plastic pots had received 65 per cent of the quantity of water given to the clay pots. Decker (4) examined the effect of the container porosity on the amount of water required by a number of ornamentals grown in a glasshouse. The water requirement of plants in non-porous containers, expressed as a percentage of that given to plants in porous containers, varied from 35 per cent for *Sansevieria* to 91 per cent for *Cineraria*. The mean for a number of species was 55 per cent. Hubbell (12) and McCall (26) have reported water requirements of 60 per cent and 77 per cent respectively for *Pelargonium* grown in non-porous containers as compared with similar plants grown in porous containers.

Knight (20) investigated the water distribution within porous pots by tensiometers and gravimetric determinations, and found that over the range, medium to high water content, there was a marked uniformity of readings on the same horizontal plane, and rarely did the difference in tension exceed 0.2 cm. of mercury. As the soil became dry the moisture content in the centre of the pot was slightly higher than that at the periphery. At this moisture content the soil pores were largely drained of moisture, and a small increase in the air content was not considered to have any significant value. These observations were made in a cool glasshouse in winter, however, and it is possible that greater differences would occur under conditions of rapid evaporation and transpiration.

Seeley (31), and Reid, Cowgill and Close (28) have employed the capillary action of the porous pot as a means of applying water to the plant. Seeley used a constant water level method in which the pots were stood on a layer of sand 1 in. above the water level. This method was suitable for 3 in. pots, but for larger pots it is recommended that the pots be plunged to the rim in the sand. This prevents evaporation from the pot wall and increases the capillary contact area. It is further recommended that the drainage be modified by using a single crock only, to give maximum contact between the soil and the pot.

Reid *et al.* (28) investigated the practice of plunging clay pots in sand or peat. They found that the rate of moisture flow through the pot wall was greater than that through the soil within the pot. The percentage water absorption by the soil within 2 in. and 4 in. pots was similar, indicating that the thickness of the pot wall and the ratio of pot wall surface to soil volume are not important. To determine the extent to which plunged pots could absorb sufficient water to meet the requirements of the plant, well established tomatoes in 2½ in. pots were either staged on an open bench, or plunged in sand, or plunged in three samples of peat at different moisture contents. The experiment was made during August and September under conditions of high temperature and much sunshine. After 48 hours the staged plants had wilted, whilst those plunged in sand remained turgid until the ninth day. The plants plunged in peat of medium moisture content did not show any wilting, and the dry weights of these plants were appreciably greater than that of the controls. Further experiments were made with *Brassica*, *Salvia* and *Withania* to determine the extent to which nutrient movement from the peat through the wall of the pot into the potting mixture occurred. A basic solution containing 17.04g. nitrogen, 17.04 g. phosphorus and 8.52 g. potash per 10 gallons of water was applied to a bed of peat 6 in. deep and 112 sq. ft. in area. All plants plunged in the peat which had been irrigated with the nutrient solution made significantly more growth than those plants plunged in peat without nutrient solution. A nutrient solution of double the above strength was found to be optimum for *Brassica* and *Salvia*, whilst with *Withania* a triple strength solution gave the best growth.

The plunging of porous clay pots in peat is widely practised by *Cyclamen* growers in the Aalsmeer (8) area, and has also been used in Germany (9).

Chemical aspects of porosity

The continual evaporation of moisture from the porous pot leads to an accumulation of salts within the clay wall. Inferior growth of tomatoes and eggplants when grown in new pots has been reported by Knott and Jeffries (21). The new pots were found to contain 0.07 mg. of nitrate nitrogen in 10 g. of pulverised clay, whereas pots of unknown history had 1.43 mg., and pots once used for growing eggplants, which had been watered three times with a nitrate solution, had 3.86 mg. On the basis of 1.43 mg. of nitrate nitrogen per 10 g. of clay it was calculated that the nitrate nitrogen within the pot wall was greater than that in the soil. In fallow pots Jones and Haskins (19) reported a progressive fall in the total soluble salt content from the centre core to the periphery, the concentration of nitrogen, phosphoric acid and potash at the periphery being approximately half of that found in the centre core.

Pollard, Smith and Rowe (27), in chemical soil studies of pot soils at Wisley, reported that the potting of a field soil markedly decreased the concentration of nitrogen phosphate and potash in the soil solution, and also that the soil solution concentration in large pots was greater than that in small pots. Examination of the leachate showed that relatively small amounts of phosphate and potsah were lost by leaching, equivalent to about 5 to 10 per cent of the amount of phosphate and 1 to 6 per cent of the amount of potash taken up by the plant. The loss of lime, however, ranged from one to ten times the amount taken up by the plant. Small pots have a larger surface area per unit weight of soil than large pots, and an inverse association was found between the concentration of the soil solution and the area of pot wall per unit weight of soil, indicating that the absorption of salts by the wall of the small pot would be relatively greater than that by the large pot. This would agree with the estimate of Jones (18) that 60 per cent of the water normally applied to a 2 in. pot was absorbed as compared to 39 per cent absorbed by a 4 in. pot. The pot wall was reported by Pollard *et al.* (27) to contain nutrients in both soluble and insoluble form, but it was concluded that the soluble nutrient would not be available to the plant as the flow of water, due

to evaporation, was practically always in the reverse direction. Whilst the concentration of nitrate and phosphate in the central core was found to be greater than that at the periphery, there was no difference in the potash levels.

In more recent experiments Eastoe and Pollard (7) found that whilst initially the soil solution in fallow porous clay pots had a lower nitrate content than that in non-porous glass pots the orders were reversed at a later sampling. The increased nitrification in the soil in the clay pot was attributed to the better aeration of the soil following the evaporation of water from the pot wall. Chemical analyses of mustard plants grown in the non-porous (glass) containers and of those grown in the clay pots of different porosity showed that the uptake of nitrogen by the plants was least in the non-porous containers, and greatest in the high porosity containers.

In a comprehensive investigation of the vertical and horizontal distribution of nutrients in leached and unleached fallow porous pots, and also in porous pots with *Coleus* and petunia grown for two and four months respectively, Knight (20) found only two definite trends with respect to the lateral distribution in the soil :

(*i*) With no leaching, and in most instances where pots were maintained fallow, the nitrate ion followed an increasing gradient from the periphery to the centre, while the gradient for potassium was the opposite.

(*ii*) Where pots received considerable leaching, either in the fallow state or with plants, the nitrate ion followed a decreasing gradient from the periphery to the centre.

There were marked differences in the vertical distribution of nutrients, however, the nitrate and potassium levels found in the top half of the pot being appreciably less than those in the lower half.

Stinson (33) investigated the chemical inhibition of algal growth which frequently develops on the outer surface of the porous pot, and reported that the growth of algae under glasshouse conditions is effectively controlled by dipping the pots into mineral spirit solutions or water emulsions of copper naphthenate containing 1.1 to 3.0 per cent copper. Certain plants grown in treated pots exhibited a change in the root distribution pattern, fewer roots showing on the surface of the ball, but were otherwise unaffected.

Effect of porosity on plant growth

Several workers (Jones (17), Jones and Haskins (19), Wilcox (35) and Hunter (14)) have reported that growth in non-porous containers was superior to that in porous containers. Eastoe and Pollard (7) and Pollard *et al.* (27), however, found that plants in non-porous (glass) containers were inferior to those in porous clay pots. The soil solution of the glass containers had a lower nutrient content than that of the clay pots, and a tentative suggestion was made that restricted bacterial action due to poorer aeration was the cause. It was thought, however, that the possibly better aeration in the clay pot was not due to the penetration of air through the pot wall but rather to the evaporation of water from the pot increasing the air content of the soil.

Plants grown in non-porous containers frequently show a lower concentration of roots on the periphery of the soil ball than similar plants grown in porous containers. Various reasons for this difference in root pattern have been advanced. Jones and Haskins (19), Hunter (14) and Pollard *et al.* (27) were of the opinion that there was an association between the nutrient content of the clay wall and root pattern, the roots developing at the point where the relatively large amount of available nitrogen is concentrated by the movement of water drawn through the pot wall by evaporation. Hubbell (13) concluded that the massed root development on the inside surface of a clay pot may be due to the high concentration of moisture held in the pores of the container,

Jones and Haskins (19) reported that plants in non-porous containers had smaller root systems, the shoot/root ratio for tomatoes in non-porous containers being 4.02 and in porous containers 3.31. Similar values have been reported by Hunter (14).

Knight (20) has studied the relationship of the shoot/root ratio and the degree of pot binding, and found that pot binding is an expression of the total mass of the plant and particularly the mass of the root. The principal factors known to influence the shoot/root ratio, i.e., aeration, moisture and nitrogen, were investigated. It was found that forced aeration of the centre of $2\frac{1}{2}$ in. pots did not change the normal root distribution pattern of stocks. A comparison of plants grown in porous and glazed containers showed that the container did not affect the pattern of root distribution of several ornamentals when they were grown at controlled soil water and nitrate levels. To maintain the same water levels in the porous pots, more frequent watering was required.

The effect of three different nitrate levels (low, medium and high) on root binding was examined. The shoot/root ratios of stocks in the three treatments after six weeks' growth were 3.7, 4.1 and 6.75 respectively. Plants in the three groups showed a uniform development up to the time that nitrogen deficiency occurred. Afterwards, in nitrogen deficient plants there was a reduction in the rate of shoot growth and a simultaneous stimulation in root development, resulting in a greater massing of the roots at the periphery.

Further examination of the root pattern of plants in pots was made by growing various plants in $2\frac{1}{2}$ in. pots which were plunged into 3 in. pots which in turn were plunged into 5 in. pots. Separation of the pots with their respective root systems showed that in all cases there was a high concentration of root on the outer surfaces and little root on the inner surfaces of the balls of soil. All three rooting media were maintained under uniform moisture tension. This massing of the roots on the outer surfaces was the result of the natural spreading habit of roots which, on reaching the pot wall, do not re-enter the soil mass but continue to develop on the periphery. It should be noted that the nutrient content of the pot wall did not form an attraction for the roots on the inner surfaces.

Knight concludes that it is unlikely that absorption of nutrients by the pot are of any significance in causing pot binding. A direct relationship was observed between the massing of the roots at the periphery and the root concentration within the soil mass. Low moisture and nitrate levels were conducive to a greater massing of roots on the periphery at a certain stage of growth than occurred when these factors were favourable.

In reviewing the literature on the effect of different soil moisture status on plant growth, Stanhill (32) reported that plants grown in containers have been found to be more responsive to differences in soil moisture status than plants grown in the field. With containers, thirty positive and one negative result were recorded, whilst for field experiments the positive results were thirty-six and the negative thirteen. The ratio is significantly smaller in field experiments than in experiments in containers.

Most of the investigators concerned with the physical properties of porous containers are of the opinion that the differences in soil temperature due to the evaporation of water from the container have no significant effect on plant growth.

Pots made from cement and plastic

Cement pots

The cement pot is a porous container but because of the large size of the pores behaves somewhat differently from the porous clay pot. Jones (18) found that the relative water utilisation of a 4 in. cement pot was 23 per cent absorbed and 77 per cent available for the soil and the plant.

For a similar size clay pot the values were 37 and 63 per cent respectively. The pore spaces in the wall of the cement pot are so large that only when the soil is excessively moist is there a capillary movement of moisture. During the greater part of the time the wall of the cement pot is dry and porous to the air.

Double-walled pots

The double-walled pot consists of two separate pots fastened together with an air-tight seal. The inner pot resembles the normal porous clay pot, whilst the outer pot is glazed to prevent water evaporation. The space between the two pots is filled with water, which is available to the plant growing in the inner pot by capillary action. The water tension can be regulated by a mercury barostat. This type of pot has been used by research workers (Wilson (36) and Richards (29)) rather than by commercial growers. Another form of double-walled pot consisting of an inner perforated pot and an outer plastic pot has been tried unsuccessfully in Holland (8).

Plastic pots

Whilst non-porous pots made from various plastics are being increasingly used by growers, there is little critical information on either their physical or chemical properties or on plant growth response. van Assche (1) has reported that tomatoes in polythene film pots showed more shoot and root growth, required less water and began picking ten days earlier than plants in conventional pots. Guyot (10) attributes the more vigorous and rapid growth of plants in plastic containers, as compared with plants grown in clay pots, to the better water and temperature regimes. Schutt and Gotzy (30), however, found that with *Primula obconica* ordinary pots (clay?) gave better results than polythene pots.

Containers made from paper, fibre, wood pulp, peat and similar materials

Paper pots

Critical investigation of paper or similar type pots has been made by Knott and Jeffries (21), Youden and Zimmerman (37), Jones (16) and Haber (11). Jones included paraffin-treated paper pots in his investigations into the effect of container materials and structure on the soil temperature within the pot. From this and other data of Jones it can be inferred that a water-proofed paper pot is similar to a non-porous pot with regard to soil temperature and water loss characteristics.

It has been conclusively established (Knott and Jeffries (21)) that the growth of tomatoes, cucumbers, cauliflowers, etc., in untreated paper pots is inferior to that produced in clay pots, and this depression in growth is caused by the competition for nitrates by the cellulose-decomposing micro-organisms and the plant (Viljoen and Fred (34)). The breakdown of the pot, with the subsequent nitrogen deficiency, can be prevented or countered in one of several ways, depending on the purpose for which the pot is required. Where it is essential that the pots retain their tensile strength and decomposition be avoided, the pot can be water-proofed with bitumen or similar material. Jones (17) treated paper pots with "Bakelite" varnish or asphalt which inhibited the breakdown, and growth of tomatoes was equal to that of plants in non-porous (glass) containers and better than that in porous clay pots.

An additional use for the bitumen-treated paper pot is in the production of early tomatoes in glasshouse borders. The tomatoes are planted from the $3\frac{1}{2}$ in. pots into the bitumen-treated paper pots, approximately 9 in. diameter, which are stood on the border soil in their cropping positions. Ultimately the tomato roots grow out of the base of the pot into the border soil. Higher soil temperatures, a better control of the plant by root restriction during the period of setting the first inflorescence, and earlier yields are among the claims made for this system of growing.

Lockie and Butters (25) reported that tomatoes grown under this system in pots filled with border soil gave a 27 per cent increase in yield to the end of May, compared with plants grown in the borders. The use of John Innes potting compost in the pots in place of the border soil gave a 41 per cent increase in yield over border grown plants.

Where plants are put into their cropping position in the borders without first removing the container it is essential that the roots quickly grow out into the border and are not confined within the pot. Pots for this purpose are not usually waterproofed, and nitrogen deficiency during decomposition of the paper will result if action is not taken to prevent it.

Youden and Zimmerman (37) recognised the importance of nitrate deficiency during the breakdown of the pot, and included in a comparison of clay, wood cellulose and fibre pots some fibre pots which had been soaked in a 1 per cent solution of sodium nitrate. A large scale field trial was made to determine the effect of the container on the growth and cropping of tomatoes. The field soil in which the tomatoes were cropped was used as the propagating medium. At planting-out stage plants in the sodium nitrate treated pots were superior to those in non-treated fibre and paper pots. The cumulative yield of the plants in the treated fibre pots was 12 per cent greater than that of plants from non-treated fibre pots. The importance of an adequate nitrogen supply in the propagating stage is illustrated by the following data. The average absorption of sodium nitrate by the treated fibre pots was 1.08 g., and 6.5 lb. of sodium nitrate absorbed by 2,720 treated pots gave an extra 5,800 lb. of fruit per acre. When the propagating soil was heavily fertilised the difference in yield due to the type of container was almost eliminated.

Knott and Jeffries (21) and Haber (11) recommend watering plants in paper and similar type containers with a solution of readily available nitrogen as often as necessary.

An alternative method of countering the low nitrogen levels associated with the decomposition of the pot has been used by Leatherman and Boswell (24). These workers prevented the normal biological decomposition of the paper pot when it is placed in the border by first dipping it in a solution of copper resinate. Treated pots placed in the field soon lost their tensile strength, allowing the roots to penetrate the pot wall, but the decomposition of the paper was inhibited. Tomatoes in treated pots were significantly better than those raised in untreated pots. There was no indication that a 12.2 per cent copper resinate solution was toxic to tomato roots.

Peat pots

In this review the term peat pot, as distinct from peat block, is used to describe containers of similar shape to the standard clay pot, and holding an equivalent amount of compost, but having the container wall made from compressed peat held together with a bonding agent.

Jones (16) reported the soil temperatures within moist peat pots to be similar to those of porous clay pots. Knott and Jeffries (21) included peat pots in the various containers investigated, and their conclusions on the peat pot are essentially similar to those for the paper and fibre containers.

Moulded blocks

There are in the main two types of moulded block which have been extensively used by growers, i.e., the peat block and the soil block. With these blocks no container is employed. The plants are grown in units of peat or compost which rely upon compression for their tensile strength.

Peat blocks

The peat block is usually a cube of compressed sphagnum peat having a shallow hole cut into the top surface into which the seedling with a small amount of compost is placed. Unlike the soil block the peat block is purchased by the grower ready made.

Knott and Jeffries (21), using lettuce, cucumber, tomato and cauliflower, compared peat blocks with other containers. Lettuce grown in peat blocks were much inferior to those grown in an equal volume of soil in a flat (seed-box). The restriction of the roots to the soil within the pricking-out hole was attributed to the acidity of the peat block, *p*H 4.2 Neutralising the pots by soaking overnight in a lime-water solution gave better root penetration, but the growth response was variable. Tomatoes responded to this treatment, whilst cucumbers did not. Neutralising the block led to more rapid decomposition of the peat, with the accompanying reduced nitrate levels. The nitrate nitrogen level of the soil in neutralised fallow blocks was 62 p.p.m., and in the control blocks 226 p.p.m. Knott and Jeffries concluded that peat blocks should be irrigated with a nutrient solution of sodium or calcium nitrate at the rate of 1 g. per gallon as often as necessary.

Soil blocks

The soil block is made by the grower by compressing potting compost. There are a number of soil block making machines available which can be classified into two basic types—those which form a block around the root of a plant, and those which produce a square or hexagonal block with a central hole in the upper surface for the seedling. Several workers have recorded increased early yields from tomatoes raised in soil blocks when compared with the standard $3\frac{1}{2}$ in. clay pot.

Lawrence (22) has investigated some of the factors involved in the use of soil blocks. The $3\frac{3}{4}$ in. soil block, used for commercial tomato propagation, was found to contain slightly less soil than a $4\frac{1}{2}$ in. pot, and had a relative compression of 1.8. Several experiments were carried out in which tomatoes and cauliflowers were grown in loose soil in $4\frac{1}{2}$ in. pots and in a similar weight of soil compressed into $3\frac{1}{2}$ in. pots. Tomatoes in the compressed soil were about 30 per cent lower in weight than those grown in the loose soil. With cauliflowers a consistent compression effect was not obtained. The larger soil surface area of the block, which is subject to evaporation, and also the absence of a rim above the soil level, as provided by the pot, makes the watering of soil blocks more difficult than that of pots. Comparison of tomatoes grown in soil blocks with those grown in an equal weight of compressed soil in a $3\frac{1}{2}$ in. pot showed that the plants in blocks usually weighed 10 to 33 per cent less than those in the pots of compressed soil. Lawrence also reported that whilst at planting-out stage plants in soil blocks were inferior to those raised in a similar amount of loose soil, the difference in the weight of ripe fruit picked in the first three weeks was only about 4 per cent in favour of the pot grown plants. He concluded that plants raised in soil blocks were able to get established in the borders more quickly than those raised in pots.

Dullforce (5, 6) has examined the effect of the container on the regeneration of transplanted seedlings. At planting-out stage there was no significant difference in weight between tomatoes, cabbage, lettuce and cauliflower raised in soil blocks and those raised in equal weight of loose soil in a $4\frac{1}{4}$ in. pot. The method of propagation did not cause any differences in the early yield. Using the percentage increase in fresh weight as the criterion it was found that in the first eight days after planting out, tomatoes in the soil blocks had a higher growth rate than plants from pots. Tomatoes grown in an equal amount of soil in a seed box received the greatest disturbance to the root system during planting out and showed the lowest growth rate, the daily percentage increase in the fresh weight for the above treatments being 10.5, 9.3 and 8.2 per cent respectively.

More recently moulded blocks of compressed vermiculite, with a base fertiliser included, have been introduced.

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9. SURVEY OF TOMATO VARIETIES GROWN UNDER GLASS IN GREAT BRITAIN, 1959

by

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This survey was carried out at the request of the Glasshouse Working Party of the Agricultural Improvement Council's Experimental Horticulture Committee. The Working Party tried to obtain information on the relative acreages of the tomato varieties growing under glass in Great Britain in order to help decide which varieties to include in experiments the Working Party was planning. No such information was found to exist. The authors, who are both members of the Working Party, were therefore asked to carry out a sample survey in order to obtain the information.

The Tomato and Cucumber Marketing Board kindly made available their 1957 list of registered growers, from which a sample was chosen. A postal questionnaire was sent out early in August 1959, and a reminder was sent out late in the month. In September, County Officers of the National Agricultural Advisory Service were asked to visit and obtain answers from approximately half of the growers who had not replied.

The growers were asked to state the tomato varieties they were using in 1959 and what area of each was grown :

(*i*) early heated, i.e., planted before March 1 and heated;
(*ii*) late heated, i.e., planted after March 1 and heated;
(*iii*) cold.

They were also asked to comment on the faults of the varieties they grew. A copy of the questionnaire is shown at the end of this article.

Choice of sample

The 1957 list of growers of the Tomato and Cucumber Marketing Board is kept on Hollerith cards and contains the names of all growers who were registered with the Board in 1957. Registration is compulsory for all growers with more than two units of production, where a unit of production, for tomatoes and cucumbers grown under glass, is :

(*i*) 5 rods of land fully planted with mature tomato plants or mature cucumber plants, or both, or
(*ii*) 500 mature tomato plants, or
(*iii*) 100 mature cucumber plants, or
(*iv*) such number of mature tomato plants and mature cucumber plants as is equivalent to 500 mature tomato plants if 5 mature tomato plants are reckoned as equivalent to 1 mature cucumber plant.

A grower with two or more whole units and a part of a unit must reckon the part as a whole unit.

The list used for sampling contained all the growers who had more than two units of production except those who grew no glasshouse tomatoes; agricultural colleges, institutes and research stations were also excluded.

The Board divide Great Britain into 13 districts (see Figure 1). Scotland and Wales make up separate districts, and groupings of the English Counties give the remaining eleven. These districts were used as strata, and a uniform sampling fraction was used for them.

The list was also stratified by size. The sampling fraction used for each size group is stated below :

1. 3- 8 units of production 1/15
2. 9-16 units of production 1/10
3. 17-32 units of production 1/5
4. 33- units of production 1/3

The practical task of choosing the sample was carried out as follows : the cards were arranged in districts, then sub-divided into the size groups stated above. Each sub-group was put into crude alphabetical order (i.e., all the A's came together but were not in strict alphabetical order) according to the grower's name. A systematic sample was then chosen from these sub-groups according to the size group it came in. Thus in a sub-group from the 3-8 units size group, a random number between 1 and 15 was chosen and the corresponding card was removed from the sub-group. Every fifteenth card after this was then chosen from the sub-group. It is believed that this method gives a substantially random sample within each stratum.

Response

The response obtained is shown in Table I. The table uses a sub-division of Great Britain which it has been found convenient to use in this report, namely into four regions :

(*i*) South of England

(*ii*) Central England

(*iii*) North of England, and Wales

(*iv*) Scotland

For details of the division see the footnote to the map in figure 1.

The total response was 85%, but it will be seen that 8% of the replies were "inadequate" which means that in the reply the total area grown was not stated or, if stated, it was not broken down according to variety, heating and time of planting. The "inadequate" replies were not used in determining the estimates.

Among the replies (35 in all) which said that tomatoes were not grown at the nursery, 50% were from nurseries which grew other crops but had ceased to grow tomatoes, and 29% were to say that the nursery had been or was about to be demolished for building.

Method of estimation

The total acreage of each variety in each of the 16 cells made up by the four regions and the four size groups was obtained. These sums were multiplied by approximate raising factors. A correction was made for the proportion of non-responders and inadequate replies. This factor equalled $n/(r\text{-}i)$ where n was the total number of questionnaires sent out, r the total response (including inadequate and nil returns) and i was the number of inadequate replies. The factor was evaluated separately for each size group within three geographical groups derived from the four regions after combining two of them. The two regions South and Central England were the ones combined as there was no significant difference between them in the response.

TABLE I

NUMBER AND TYPE OF REPLIES OBTAINED TO QUESTIONNAIRES

Region	Type of reply	Size group				Total	Percentage
		1	2	3	4		
South England	Useful	44	14	19	16	93	73.2
	Inadequate	4	1	1	–	6	4.7
	No tomatoes	3	1	2	1	7	5.5
	No response	9	6	3	3	21	16.6
	Total	60	22	25	20	127	100.0
Central England	Useful	40	21	22	56	139	67.1
	Inadequate	5	1	1	5	12	5.8
	No tomatoes	5	–	6	9	20	9.7
	No response	10	6	7	13	36	17.4
	Total	60	28	36	83	207	100.0
North England and Wales	Useful	62	20	20	15	117	75.5
	Inadequate	9	3	3	4	19	12.3
	No tomatoes	3	1	-	1	5	3.2
	No response	8	3	2	1	14	9.0
	Total	82	27	25	21	155	100.0
Scotland	Useful	11	5	6	8	30	60.0
	Inadequate	2	3	3	–	8	16.0
	No tomatoes	1	–	2	–	3	6.0
	No response	4	3	1	1	9	18.0
	Total	18	11	12	9	50	100.0
GREAT BRITAIN	Useful	157	60	67	95	379	70.3
	Inadequate	20	8	8	9	45	8.4
	No tomatoes	12	2	10	11	35	6.5
	No response	31	18	13	18	80	14.8
	Total	220	88	98	133	539	100.0

Accuracy of estimates

Two possible sources of error in the estimates should be noted. These would apply if a complete census and not a sample survey had been made. They are:

(*i*) use of an out-of-date list

(*ii*) lack of knowledge of non-responders.

It is believed to be doubtful that much error was introduced by using a 1957 list and therefore ignoring growers of tomatoes who began after 1957. For according to the Tomato and Cucumber Marketing Board's statistics, the number of producers in the size groups considered in the survey decreased from 5,201 in 1957 to 4,786 in 1959; a fall of 8%. Because of this decrease it seems doubtful that there would be many names in a 1959 list which were not already in the 1957 list.

A check on the non-responders was obtained by comparing the replies obtained by N.A.A.S. County Officers from growers who did not reply immediately, with the replies obtained by post. The proportion of the sample from which a response was obtained in this way was about 8%. The answers from this set of replies were similar to those obtained from the remainder of the replies, though a completely satisfactory test of the comparison could not be made because some of the numbers involved were small.

FIGURE 1. Area covered by the tomato variety survey.

The numbers denote the districts used by the Tomato and Cucumber Marketing Board for their records. For the presentation of the survey data the districts were combined into the following regions, which are shown delimited by heavy lines:

South England VIII, IX, X, XI
Central England III, V, VI, VII
North England and Wales I, II, IV, XII
Scotland XIII

An attempt to check the estimates was made by comparing the survey estimate of total acreage of glasshouse tomatoes with other known estimates. The Tomato and Cucumber Marketing Board give the total number of units of production of glasshouse tomatoes from their registered producers in 1959 as 60,052. If this is decreased by the estimated number of units grown by producers having not more than two units (who registered without being obliged to do so) the number is 59,147. The unit of production has been defined above and may be strictly 1/32 acre or, if based on number of plants, it may be from 1/32 to 1/25 acre according to whether the spacing is taken to be 16,000 plants per acre or 12,500 plants per acre (which should cover the normal range of spacings used). The total acreage in Great Britain should therefore be between 1,848 and 2,366 acres. The estimate obtained in the survey is 2,059 acres, which seems consistent with the Tomato and Cucumber Marketing Board's figures. Because of the ambiguity in the definition of a unit, however, the check is not an entirely satisfactory one.

Another estimate may be obtained from the figures issued by the Ministry of Agriculture, Fisheries and Food. The figure of 2,268 acres is given for England and Wales, and 246 acres for Scotland, to give a total acreage in Great Britain of 2,514. The census was limited to occupiers of holdings with more than one acre of land used for agriculure, and with not less than 1,000 square feet of glass (excluding lights and cloches). It will be recalled that the survey being reported was limited to growers with more than two units of production, i.e., more than approximately 2,700 square feet of glass. It would therefore be expected that the Ministry estimate would be higher than the Tomato and Cucumber Marketing Board estimate, but not to the extent that it is. This discrepancy gives grounds for suspecting that the survey estimates are low in the estimates of absolute acreage; but it seems reasonable to presume that the relative acreages will be approximately correct.

The sampling error must next be considered. The standard errors of the estimates of total acreage for each variety with an estimated acreage of over 10 acres were calculated, and are included in Table II.

Results

The results are presented in a series of four tables. In all tables the figures are divided according to the four regions which have been chosen to separate the main growing areas in the country. "South England" contains the Worthing area, "Central England" the Lee Valley, "North England and Wales" the Lancashire and East Yorkshire areas (Wales makes little contribution), and "Scotland" makes another distinct area.

Table II is the main table, and gives the estimated area of each variety. The varieties are arranged in descending order of the total area of each in Great Britain, and the standard error of the total acreage of each variety named is stated. The first four varieties stand out from the remainder, but otherwise there are few significant differences, at the 5% level, between pairs of varieties. The reason for this will be seen from Table III, which gives the percentage of growers using each variety in each region and in Great Britain. Except for the first four varieties, each variety is grown by well less than 10% of all growers. The sample is therefore based on few replies for the less common varieties and does not distinguish well between them. An arbitrary figure of 10 acres was chosen, and only those varieties with an estimated area of over 10 acres are included in the Table. This gives a list of 24 varieties, though 70 distinct varieties (listed on page 138) were reported in the survey. The high position of 'Carrick' in the table is believed to be suspect, and it will be noted that the area estimate has a high standard error. The sample contained one grower with an extremely large acreage of 'Carrick', although it will be noted from Table III that it is estimated that 'Carrick' is grown by only 0.7% of all growers.

TABLE II

ACREAGE OF VARIETIES OF WHICH IT IS ESTIMATED MORE THAN 10 ACRES WERE GROWN IN GREAT BRITAIN IN 1959

Variety	South England	Central England	N. England and Wales	Scotland	Great Britain	(± s.e.)
Moneymaker	146.0	177.3	168.9	163.2	655.4	±42.7
Potentate	60.5	278.3	13.2	—	352.0	±74.0
Ware Cross	100.5	81.5	71.0	52.7	305.7	±36.3
Ailsa Craig	18.6	40.7	47.3	8.5	115.1	±18.9
Syston Cross	8.9	28.7	13.0	0.8	51.4	±12.9
Carrick	—	51.2	—	—	51.2	±39.6
J.R.6	3.7	9.9	25.0	5.2	43.8	±10.6
Baby Lea	3.4	36.0	—	—	39.4	±10.5
Antimold 'A'	3.2	3.0	18.4	—	24.6	± 7.2
Dutch Victory	10.2	11.5	1.9	—	23.6	± 8.6
E.S.5	0.2	6.3	15.2	1.4	23.1	± 6.8
E.S.1	2.3	9.9	9.5	—	21.7	± 6.9
Discovery	—	7.4	1.6	12.1	21.1	± 6.1
Potential	0.1	3.3	15.4	2.1	20.9	± 7.2
Clucas 99	2.9	—	14.5	—	17.4	± 7.0
Exhibition	7.9	2.9	3.7	2.3	16.8	± 6.0
Kondail	10.7	5.3	—	—	16.0	± 9.1
Melville Castle	1.5	1.7	10.5	2.5	16.2	± 6.0
Single Cross	6.0	8.0	1.2	—	15.2	± 5.3
Hertford Cross	4.3	9.3	0.8	—	14.4	± 5.3
Star	2.4	3.8	6.3	0.8	13.3	± 4.0
Hundredfold	3.6	7.8	0.8	—	12.2	± 4.7
Fortuna	0.7	7.0	2.6	1.9	12.2	± 6.9
Radio	2.8	—	7.8	0.4	11.0	± 3.9
Total	400.4	790.8	448.6	253.9	1893.7	
Remaining varieties	35.9	31.1	80.9	17.4	165.3	
Total for all varieties	436.3	821.9	529.5	271.3	2059.0	±104

Table II (*a*) restates the information in Table II by expressing all acreages as a percentage of the total acreage grown in the particular region.

The same list of varieties is used in Tables II, II (*a*) and III. The majority of growers use more than one variety so that in the latter two tables each column does not add up to 100.

Tables IV and V have been compiled in order to show how the area of the four leading varieties is made up according to type of crop and size of holding respectively. The definitions of the type of crop have been given earlier. The definitions of the size of holding, used in Table V, are :

Small=3-8 units (approximately 1/16-1/4 acre)

Medium=9-32 units (approximately 1/4-1 acre)

Large=33 or more units (approximately over 1 acre)

The size of a particular holding was determined by reference to the number of units of production at the holding as given in the 1957 list of the Tomato and Cucumber Marketing Board. Hence the size grouping is based on the area of tomatoes and cucumbers grown by the holding in 1957.

TABLE II (*a*)

PERCENTAGE AREA OF VARIETIES OF WHICH IT IS ESTIMATED MORE THAN 10 ACRES WERE GROWN IN GREAT BRITAIN IN 1959

Variety	South England	Central England	N. England and Wales	Scotland	Great Britain
(*acres*)	(*436*)	(*822*)	(*530*)	(*271*)	(*2059*)
Moneymaker	33.5	21.6	31.9	60.2	31.8
Potentate	13.9	33.9	2.5	—	17.1
Ware Cross	23.0	9.9	13.4	19.4	14.8
Ailsa Craig	4.3	5.0	8.9	3.1	5.6
Syston Cross	2.0	3.5	2.5	0.3	2.5
Carrick	—	6.2	—	—	2.5
J.R.6	0.8	1.2	4.7	1.9	2.1
Baby Lea	0.8	4.4	—	—	1.9
Antimold 'A'	0.7	0.4	3.5	—	1.2
Dutch Victory	2.3	1.4	0.4	—	1.1
E.S.5	—	0.8	2.9	0.5	1.1
E.S.1	0.5	1.2	1.8	—	1.1
Discovery	—	0.9	0.3	4.5	1.0
Potential	—	0.4	2.9	0.8	1.0
Clucas 99	0.7	—	2.7	—	0.8
Exhibition	1.8	0.4	0.7	0.8	0.8
Kondail	2.5	0.6	—	—	0.8
Melville Castle	0.3	0.2	2.0	0.9	0.8
Single Cross	1.4	1.0	0.2	—	0.7
Hertford Cross	1.0	1.1	0.2	—	0.7
Star	0.6	0.5	1.2	0.3	0.6
Hundredfold	0.8	0.9	0.2	—	0.6
Fortuna	0.2	0.9	0.5	0.7	0.6
Radio	0.6	—	1.5	0.1	0.5
Remainder	8.2	3.8	15.3	6.4	8.0

TABLE III

PERCENTAGE OF HOLDINGS IN EACH REGION ON WHICH A VARIETY IS GROWN (ONLY VARIETIES WITH AN ESTIMATED ACREAGE EXCEEDING 10 ARE INCLUDED)

Variety	South England	Central England	N. England and Wales	Scotland	Great Britain
Moneymaker	58.6	52.0	58.0	94.7	59.7
Potentate	13.1	21.2	3.9	—	11.2
Ware Cross	34.7	29.4	27.0	33.4	30.3
Ailsa Craig	8.2	6.5	15.7	11.8	10.6
Syston Cross	5.3	7.4	5.3	0.8	5.5
Carrick	—	2.2	—	—	0.7
J.R.6	4.3	4.4	10.7	6.7	6.7
Baby Lea	2.4	5.5	—	—	2.3
Antimold 'A'	4.3	5.8	11.7	—	6.9
Dutch Victory	3.5	2.2	0.2	—	1.7
E.S.5	1.1	0.5	8.5	1.7	3.5
E.S.1	3.8	1.8	3.9	—	2.9
Discovery	—	2.3	1.6	16.2	2.7
Potential	0.5	1.9	3.7	0.8	2.1
Clucas 99	2.7	—	9.4	—	3.9
Exhibition	3.0	0.5	3.0	10.3	2.9
Kondail	2.1	1.2	—	—	0.9
Melville Castle	1.6	0.9	3.1	5.1	2.2
Single Cross	1.9	4.9	2.0	—	2.7
Hertford Cross	1.4	2.8	1.2	—	1.6
Star	3.3	1.0	3.1	0.8	2.3
Hundredfold	2.1	7.9	1.2	—	3.4
Fortuna	1.7	2.4	0.4	0.8	1.4
Radio	3.0	—	5.4	5.2	3.1

TABLE IV

PERCENTAGE AREA OF THE FOUR MOST COMMON VARIETIES ACCORDING TO TYPE OF CROP

	South England	Central England	N. England and Wales	Scotland	Great Britain
Early heated: (*acres*)	(*182*)	(*465*)	(*59*)	(*182*)	(*889*)
Moneymaker	15.0	10.1	33.3	59.8	22.7
Potentate	27.6	47.4	5.7	—	30.9
Ware Cross	33.9	8.6	21.2	26.0	18.2
Ailsa Craig	4.2	3.2	4.8	3.3	3.5
Remainder	19.3	30.7	34.9	10.9	24.6
Late heated: (*acres*)	(*98*)	(*186*)	(*257*)	(*81*)	(*622*)
Moneymaker	36.0	28.9	33.4	62.5	36.1
Potentate	5.7	26.5	0.5	—	9.2
Ware Cross	15.9	4.8	15.4	6.8	8.0
Ailsa Craig	7.0	10.0	8.4	1.3	7.8
Remainder	35.4	29.8	42.3	29.5	35.8
Cold: (*acres*)	(*156*)	(*171*)	(*213*)	(*8*)	(*548*)
Moneymaker	53.1	45.0	29.6	36.0	41.3
Potentate	3.2	6.5	3.9	—	4.5
Ware Cross	14.8	19.2	8.7	—	13.6
Ailsa Craig	3.0	3.9	10.9	20.0	6.5
Remainder	25.9	25.4	46.9	44.0	34.1

TABLE V

PERCENTAGE AREA OF THE FOUR MOST COMMON VARIETIES ACCORDING TO SIZE OF HOLDING

	South England	Central England	N. England and Wales	Scotland	Great Britain
Small (*acres*)	(*177*)	(*124*)	(*195*)	(*74*)	(*570*)
Moneymaker	48.7	42.1	30.0	77.4	44.5
Potentate	5.1	8.4	0.2	—	3.4
Ware Cross	24.6	19.3	11.9	12.6	17.6
Ailsa Craig	0.3	2.8	7.5	—	3.3
Remainder	21.3	27.4	50.4	10.0	31.2
Medium (*acres*)	(*138*)	(*197*)	(*214*)	(*99*)	(*648*)
Moneymaker	23.3	31.5	28.3	64.6	33.5
Potentate	16.6	18.3	6.1	—	11.3
Ware Cross	20.9	11.9	11.0	8.5	13.1
Ailsa Craig	11.4	0.9	8.4	3.7	6.0
Remainder	27.9	37.4	46.2	23.1	36.1
Large (*acres*)	(*121*)	(*500*)	(*121*)	(*99*)	(*841*)
Moneymaker	22.8	12.5	41.2	42.5	21.6
Potentate	23.9	47.0	—	—	31.4
Ware Cross	23.3	6.8	19.9	35.5	14.4
Ailsa Craig	1.9	7.1	12.4	5.0	6.9
Remainder	28.1	26.6	26.6	17.0	25.7

Discussion

The survey has provided interesting and very useful information on the varieties grown and their relation to district, size of holding and time of planting.

Varieties

The number of varieties grown was surprisingly large, totalling seventy after known synonyms had been eliminated. It is questionable whether this large number of varieties is needed, as many are similar in character. Such a large number must make for unnecessary complexity in the seed trade, where at least one firm lists over fifty varieties and several list twenty-five to thirty.

Four varieties, 'Moneymaker', 'Potentate', 'Ware Cross' and 'Ailsa Craig', account for 69% of the total acreage and provide for the main needs of the industry. 'Moneymaker' is outstandingly the most commonly grown variety with 32% of the total acreage, followed by 'Potentate' with 17%, 'Ware Cross' with 15% and 'Ailsa Craig' with 6%. Of the remaining 64 varieties recorded in the survey, ten each occupy 1-3% of the total acreage, ten 0.5-1% and 46 each have a total area of less than ten acres.

'Moneymaker' was expected to be the most widely grown variety, but its outstanding position, occupying one-third of the total area and nearly twice the area of any other variety, was surprising. The variety does well under a wide range of conditions, produces a well coloured, round fruit of medium size and, because of the even ripening character of its fruit, is virtually free from green-back. It must be this combination rather than any single character which makes the variety so popular.

'Ware Cross' is the only F_1 hybrid grown on any scale. F_1 hybrids as a whole account for 19% of the total area, of which 'Ware Cross' occupies 15%, 'Syston Cross' 3% and the rest 1%. Considering the number of F_1 hybrids which have been introduced it is interesting that only 'Ware Cross' and 'Syston Cross' have made any impact in Great Britain. 'Ware Cross' is a universally popular variety, the combination of 'E.S.1' and 'Potentate' appearing to confer a reduced sensitivity to environment.

Varieties resistant to *Cladosporium* are not popular, probably because they are generally low yielding and the disease is, in any case, relatively easy to control on most holdings by cultural means and spraying. Mildew-resistant varieties returned were twelve in number and account for less than 6% of the acreage. 'Syston Cross' is the most widely grown with 51 acres, followed by 'J.R.6' (44 acres) and 'Antimold A' (25 acres).

Growers were asked to comment on faults in the varieties they grew. A summary of the comments in respect of the three main varieties is given in Table VI.

There were many complaints of the quality of 'Potentate' and 'Ware Cross' in respect of poor shape and uneven colouring. 'Moneymaker' was commented on favourably for quality, with the exception of some adverse criticism of small size. 'Moneymaker' seemed to give some trouble with *Cladosporium*, particularly in the south, and was not liked by some growers for its slowness in ripening and a tendency to run out in the top in mid-season. 'Ware Cross' and 'Moneymaker' were felt by some to be too vigourous.

These comments are helpful in that they point to characters the grower wants in an early variety —round fruit of medium size and uniform colour, resistance to *Cladosporium*, early ripening, compact habit, but with sufficient vigour to maintain cropping in mid-season.

TABLE VI

PERCENTAGE OF GROWERS IN SAMPLE WHO COMPLAINED OF FAULTS WITH THE VARIETIES THEY WERE GROWING. THE FIGURES ARE GIVEN AS PERCENTAGES OF THE NUMBER OF GROWERS USING THE VARIETY

	Moneymaker	Potentate	Ware Cross
Number of growers in sample using the variety	211	74	121
Faults complained of:	%	%	%
Poor shape and size	7	34	27
Blotch	–	15	9
Greenback	–	5	15
Cladosporium	16	6	11
Other diseases	6	1	4
Too much vigour	4	–	6
Late ripening	9	–	–
Tendency to run out after 5 trusses	11	–	–
No comment, or praise	52	43	35

Region

There is some correlation between varieties and region. Though 'Moneymaker' is the most widely grown variety generally, it is most popular in the southern, northern and Scottish regions and is replaced in first position by 'Potentate' in central England. 'Moneymaker' is particularly popular in Scotland, where it is grown on 95% of the holdings in contrast to 50-60% in other regions. 'Potentate' is grown mainly in central England, where it accounts for 34% of the total acreage. It is hardly grown in northern England, and there was no return of it from Scotland. The main stronghold of this variety is the Lee Valley, and without the big acreage in this area the variety would be of secondary interest. 'Ware Cross' is a uniformly popular variety, being grown by about 30% of growers in all areas. It accounts for 23% of the total acreage in the southern region, 19% in Scotland and 10% in central England. It is the second most important variety in Scotland, together with 'Moneymaker' accounting for 80% of the total area. 'Ailsa Craig' is most popular in central and northern England, as are the mildew-resistant varieties. The variety 'Discovery' is popular in Scotland but not elsewhere. There are two distinct varieties distributed under the name 'Discovery', one a round fruited type introduced by Clapham & Sons of Enfield, the other a 'Potentate' type introduced by Naftel of Guernsey. The Clapham variety is the one grown in Scotland and central England; the Naftel variety ,so far as can be determined, is little grown in Great Britain.

Size of holding

Size of holding correlates with the variety grown in the case of 'Potentate' and, in Scotland, of 'Ware Cross'. 'Potentate' is mainly used by the big grower. In the central district it is only grown on 21% of holdings but accounts for 47% of the large growers' total acreage, in contrast to 18% for medium size and 8% for small size holdings. 'Ware Cross' is not influenced by size of holding except in Scotland where the variety is favoured by large growers.

Time of planting

The division of crops into early heated and late heated is purely arbitrary. The dividing point at March 1st may be criticised, particularly by early growers in the southern region, as being late for many early crops, but considering the need to keep the questionnaire brief and simple the date is a reasonable compromise.

In the early heated crop 'Potentate' occupied 275 acres, 'Moneymaker' 202 acres and 'Ware Cross' 162 acres. 'Potentate' is favoured for early work in central England, 'Ware Cross' and 'Potentate' in southern England ,and 'Moneymaker' in Scotland. For the late heated crop 'Moneymaker' predominates, though 'Ailsa Craig' is also used in central and northern England. For cold crops 'Moneymaker' is most widely grown and accounts for 41% of the total area.

'Potentate' has been accepted as an early variety, but this has recently been put in doubt by Darby whose results from variety trials at this Institute over four years suggest that 'Ailsa Craig' is earlier ripening and earlier bulking. The two varieties most widely grown early in each region are :

South	*Central*	*North*	*Scotland*
'Ware Cross'	'Potentate'	'Moneymaker'	'Moneymaker'
'Potentate'	'Moneymaker'	'Ware Cross'	'Ware Cross'

The quality of 'Potentate' is rarely good, and its choice for early work in central and southern districts is dictated by the fact that it is less difficult to handle in the early period after planting and there is less chance of failure than with vigorous varieties like 'Ailsa Craig'. 'Potentate' is, however, rejected as an early variety by Scotland and northern England in favour of 'Moneymaker'. This choice is not easy to understand as 'Moneymaker' is more difficult to grow than 'Potentate', climatic conditions are less favourable in the north and 'Moneymaker' is reported to be a slow ripening variety. The choice may be dictated by quality considerations as it is difficult to sell large and irregular shaped fruit, such as are produced by 'Potentate', in northern England and Scotland.

Distribution of production

From Tables VII and VII (*a*) it is useful to note the manner in which tomato production is distributed in relation to type of crop, acreage and district. On an acreage basis the bulk of the early production is in the central region (Lee Valley), late heated in the northern region (Lancashire) and cold also in the northern region (East Yorkshire). Early production accounts for 43% of the total acreage, late heated 30% and cold 27%. Scotland is exceptional in devoting 67% of its acreage to early production. The southern region concentrates on early heated and cold, central England and Scotland on early heated, and the north on late heated and cold production.

TABLE VII

DISTRIBUTION OF TOMATO PRODUCTION IN EACH REGION ACCORDING TO TIME OF PLANTING, AS PERCENTAGE OF TOTAL AREA FOR EACH REGION

	South England	Central England	N. England and Wales	Scotland	Great Britain
Early heated	42	56	11	67	43
Late heated	22	23	49	30	30
Cold	36	21	40	3	27

TABLE VII (*a*)

REGIONAL DISTRIBUTION OF TOMATO CROPS PLANTED AT DIFFERENT TIMES AS PERCENTAGE OF TOTAL PRODUCTION WITHIN EACH GROUP

	South England	Central England	N. England and Wales	Scotland
Early heated	20	52	7	21
Late heated	16	30	41	13
Cold	28	31	39	2
Total	21	40	26	13

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THE QUESTIONNAIRE

Area of tomatoes being grown in 1959 (state in sq. ft.)			
Planted	Before March 1	After March 1	
	Heated	Heated	Cold
1.			
2.			
3.			
4.			

(Include any further varieties below)
What are the faults of these varieties?

VARIETIES NAMED IN THE SURVEY

(A variety in brackets after a given variety is taken to be synonymous with it)

1. A.B.Seedling
2. Ailsa Craig
3. Aldourie (Aldourie Seedling)
4. All Clear (Stonor's All Clear)
5. Allround
6. Antimold 'A'
7. Antimold 'B'
8. AR6/A
9. Auchincruive (Auchincruive 1A, Auchincruive No. 5)
10. Baby Lea
11. Best of All
12. Bonne Chose
13. Carrick
14. Cavendish Perfection
15. Cluseed 99 (Cluseed Maincrop 99, Cluseed Early 99, Clucas 99)
16. Corleys
17. Coronet
18. Discovery
19. Duffern's Seedling
20. Dutch Victory
21. Early Market
22. Early Sunrise (Carter's Early Sunrise)
23. E.S.1.
24. E.S.5.
25. Exhibition (Stonor's Exhibition)
26. Fortuna
27. Glorie
28. Growers Pride (Pride)
29. Harbinger
30. Hertford Cross
31. Hundredfold
32. Immuna
33. J.H.1.
34. J.H.2.
35. J.P.
36. J.R.6.
37. Kondail
38. Kromcamp
39. L.M.R.1. (L.M.R., Resistant No. 1, R.1)
40. Market King
41. Melville Castle
42. Moneymaker
43. M.P. (Stonor's M.P.)
44. Northern Queen
45. Osmaston Market
46. Planet
47. Plumpton King
48. Potato Leaf Variety (Badsey Potato Leaf)
49. Potentate
50. Potential
51. Poultonian
52. Radio
53. Runover
54. Sapsford's No. 1
55. Scarlet Emperor
56. Scarlet Knight
57. Silverdale
58. Single Cross
59. Star
60. Superlative (Dunn's Superlative)
61. Syston Cross
62. Tukon
63. Tukster (Dutch)
64. V.49
65. Vanguard (Stonor's Vanguard)
66. Vetomold
67. Victory
68. Ware Cross
69. Wokingham Wonder
70. Yellow

APPENDIX

PUBLICATIONS 1959

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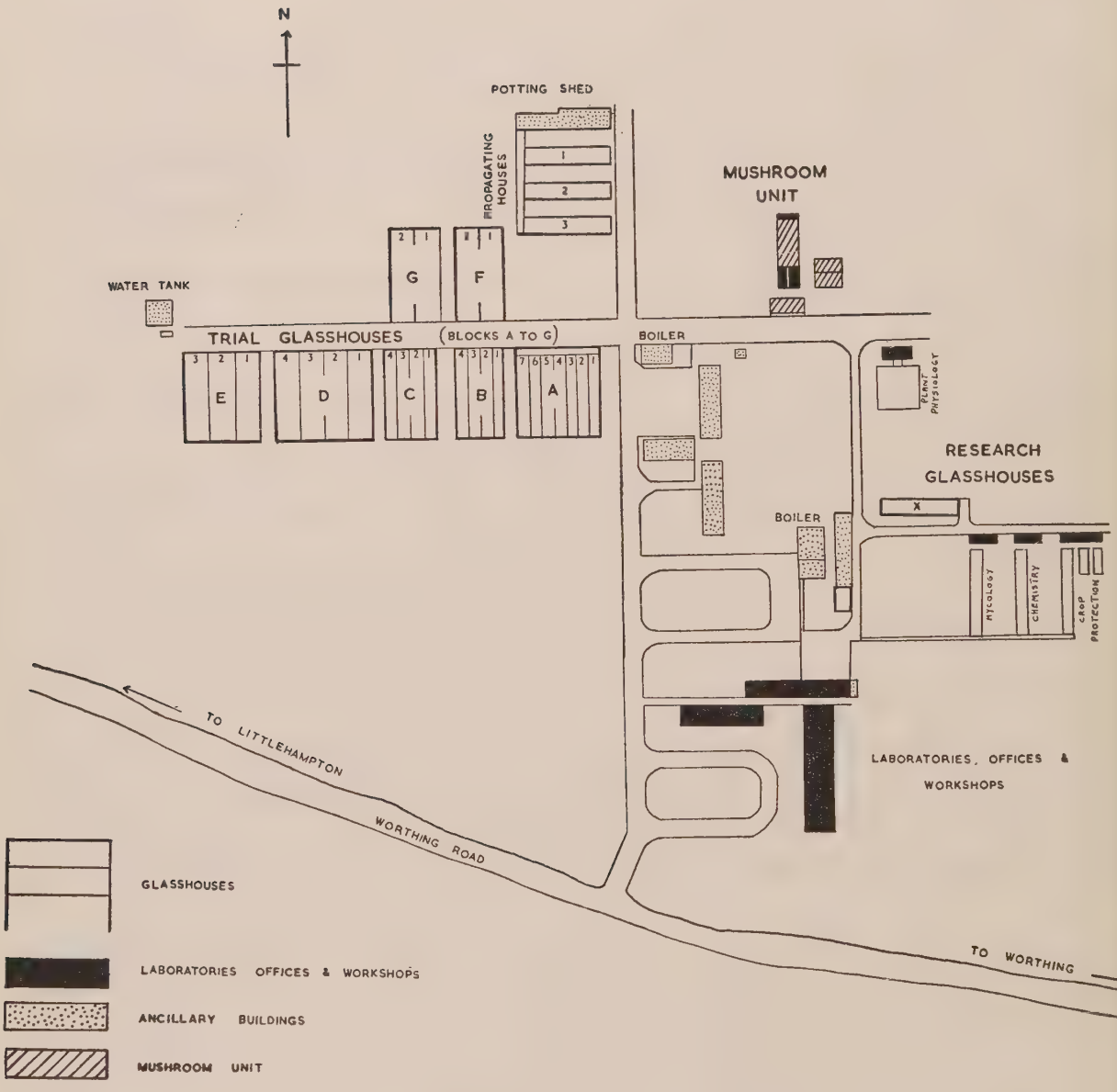

Layout of the glasshouses, laboratories, and other buildings

THE JOURNAL OF HORTICULTURAL SCIENCE

THE JOURNAL OF HORTICULTURAL SCIENCE, which is sponsored by the Long Ashton Research Station and the East Malling Research Station, welcomes contributions on horticultural science from Research Institutes at home and abroad. Papers for publication and all communications should be sent to the Editors at East Malling Research Station, Maidstone, Kent.

Papers in the current VOLUME 35 (1960) and already accepted towards the next, in addition to those from the sponsor Stations, come from Rustington, Wellesbourne and Mylnefield, from London, Reading, Nottingham and Manchester Universities; and from Canada, South Africa, India, Ghana and the British West Indies.

Of particular interest to growers of glasshouse crops are papers describing the study of the growth of tomatoes, the effects of plant form and planting density on the yield of that crop, soil salinity, and low temperature effects on the flowering of chrysanthemums.

Studies are reported on many fruits grown in the open. While most of these relate to apples, there are also papers dealing with plums, peaches, black currants, raspberries and strawberries; bananas, citrus fruits, custard apples and cocoa are also included, and there are two papers on the nutrition of hops. Papers on vegetables are concerned with summer cauliflower, runner and French beans and radishes.

Amongst the many and diverse subjects of research reported in these papers may be mentioned nutrition, rootstocks, including stock/scion compatibility, propagation, pruning, environmental studies, diseases, weed control, fruit storage and experimental technique.

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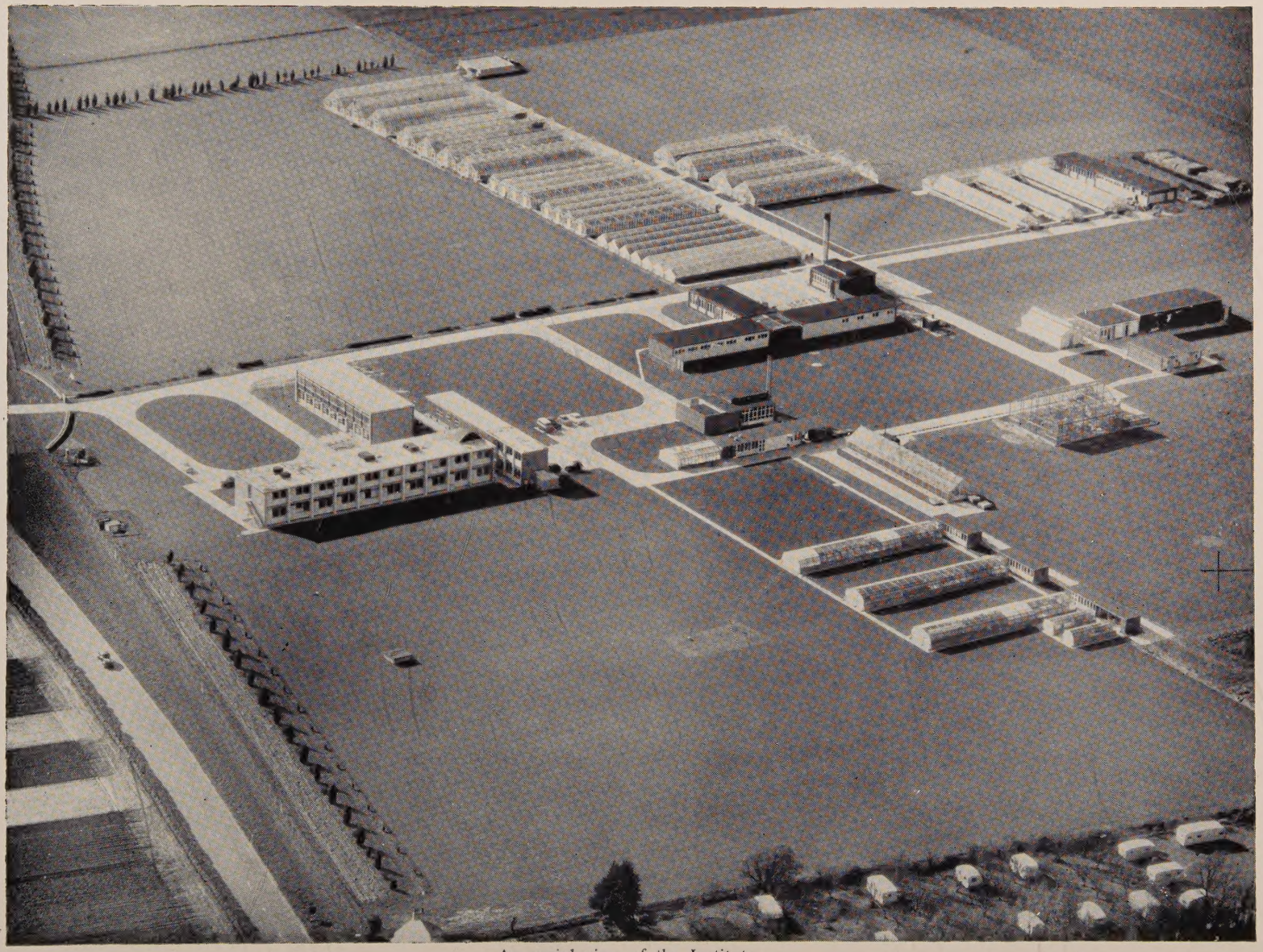

An aerial view of the Institute